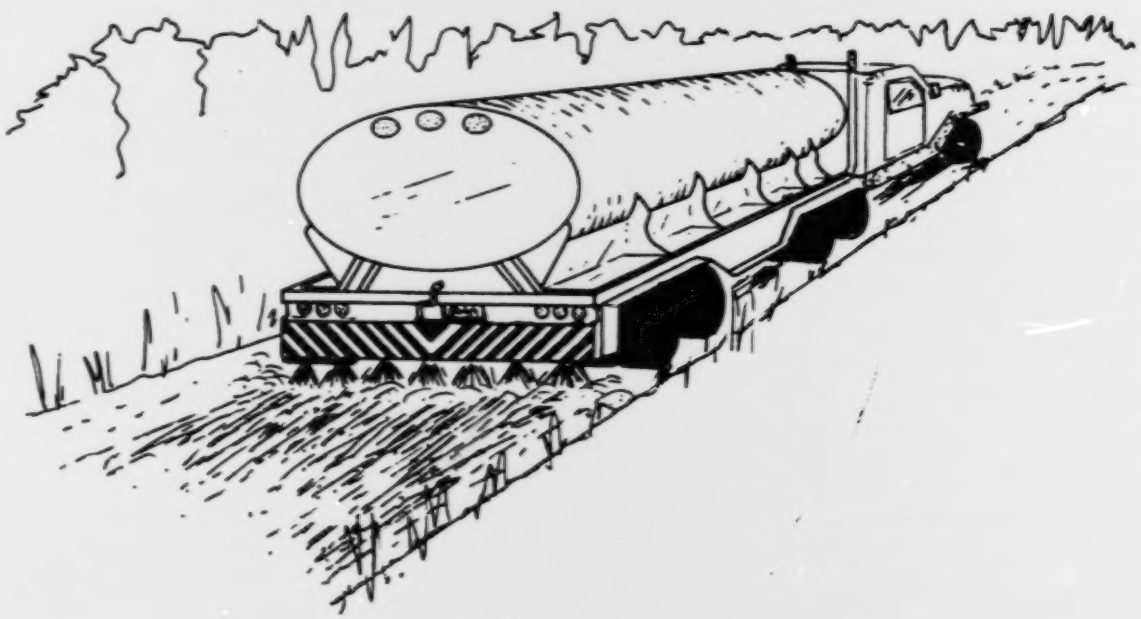
ROAD DUST SUPPRESSION IN NORTHERN AND WESTERN CANADA

REVIEW OF ALTERNATIVES AND EXISTING PRACTICES

FOR

ENVIRONMENT CANADA
ALBERTA ENVIRONMENT
MINISTRY OF ENVIRONMENT, BRITISH COLUMBIA
MANITOBA ENVIRONMENT
NORTHWEST TERRITORIES ENVIRONMENTAL SERVICES



TECHMAN ENGINEERING LTD.

MAY, 1982

Energy Project Designers and Constructors

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May 27, 1982

Mr. Griff Sherbin
Head Water Pollution & Contaminants Control
Environmental Protection Service
804, 9942 - 108 Street
Edmonton, Alberta
T5K 2S5

Dear Mr. Sherbin:

Re: Road Dust Suppression in Northern and Western Canada

Techman Engineering Ltd. is pleased to submit the final report of the "Road Dust Suppression in Northern and Western Canada Study". The report consists of two self supporting documents. The first is entitled "Review of Alternatives and Existing Practices" and describes the principles of dust formation, the mechanics of dust suppression, and the effects of dust and dust suppressants on the environment. The second document is entitled "Manual of Recommended Procedures" and is designed to assist those directly involved with making "dust control decisions" in selecting suppressants which are environmentally safe and cost effective.

We would like to thank the Steering Committee for the cooperation and advice provided during the study.

Yours truly,
TECHMAN ENGINEERING LTD.

W. Siemieniuk

W. Siemieniuk, M.N.R.M.
Environmental Sciences

WS:ECP
Encls.

926 - 5th Avenue S.W., P.O. Box 2840, Calgary, Alberta, T2P 2M7 • Telex: 03-821485 • 403/294-6270

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MAY, 1982

TECHMAN ENGINEERING LIMITED

CALGARY, ALBERTA

EXECUTIVE SUMMARY

This report presents the findings of the Review of Alternatives and Existing Practices step of the Road Dust Suppression in Northern and Western Canada study. The study was commissioned by the Federal Environmental Protection Service in association with the Environment Departments of Alberta, British Columbia, Manitoba and Northwest Territories.

REPORT OBJECTIVES

The objectives of this report are:

- o to examine the technical and environmental aspects of road dust generation;
- o to review technical, environmental and economic aspects of road dust suppressants;
- o to identify existing road dust suppression practices in northern and western Canada; and
- o to identify research and development needs.

Information addressing the objectives was collected primarily through a literature search and interviews with government environment and transportation officials, road dust suppressant suppliers and transportation associations. The main findings of the study are summarized in the following sections.

ROAD DUST GENERATION

Road dust is generated by passing vehicles in three ways:

- o vortex entrainment;
- o slippage entrainment; and
- o saltation and creep of larger particles.

Vortex entrainment refers to a passing vehicle compressing and expanding air as it travels over a road surface. The compression and expansion serves to pump dust into the air.

Slippage entrainment refers to the suspension of material in the contact zone between the tire of the vehicle and the road surface. Slippage entrainment occurs in three phases and is responsible for approximately 90 percent of road dust generated by a passing vehicle:

- o phase 1 - as the wheel approaches, the particle is forced forward and out with an abrading effect. (at this point vortex entrainment is also involved);
- o phase 2 - when the vehicle is directly overhead, the particle is forced downward with a crushing effect; and
- o phase 3 - when the vehicle leaves, the particle is forced backward and out with an abrading effect (saltation and creep of aggregate also involved here).

Saltation and creep of large aggregate particles also contribute to road dust generation. Saltation describes the process by which large aggregate particles suspended by slippage entrainment strike and suspend other road surface particles. Surface creep refers to the rolling of large heavy particles along the road surface. These large particles were not able to be suspended into the air by a saltating particle.

The rate and amount of road dust generated by the above three mechanisms, is dependent upon the following factors:

- o vehicle speed;
- o number of wheels/vehicle;
- o particle size distribution;
- o surface moisture index;
- o vehicle weight;
- o vehicle cross section;
- o tire width;

- o tire design;
- o length of unpaved road; and
- o design of roadway.

Road dust, once suspended, is composed of a wide variety of particulates which may have diverse physical and chemical characteristics. The primary factor affecting particulate characteristics is the composition of the road surface aggregate. In northern and western Canada, road aggregate is derived primarily from four classes of material:

- o glaciofluvial sand and gravel;
- o crystalline rocks;
- o sedimentary rocks, primarily carbonates; and
- o glacial till.

Chemically, studies of the composition of road dust indicates that calcium, sodium, magnesium, potassium, phosphorous and nitrates may be present, depending on the aggregate material.

Physically, studies have identified three important sizes of road dust:

- o > 10 microns-represents large particles suspended by a moving vehicle, the largest of which are capable of damaging or breaking windshields, headlights or automobile trim;
- o > 2 microns but < 10 microns-represents visible suspended dust particulates; and
- o < 2 microns-comprises particulates which have the potential for maximum deposition in the lungs.

The size of road dust particles suspended, directly affects the rate of particle deposition and the distance travelled by a particle from the original suspension point. Dust data collected along roadways, has shown that the majority of road dust deposition is within 30 metres of the centreline.

IMPACTS OF ROAD DUST

The generation of road dust has environmental and social implications. Specific impact areas include:

- safety;
- aesthetics;
- health;
- vegetation;
- soils; and
- aquatic resources.

With respect to safety, the loose surface aggregate of unpaved roads contributes to a loss of visibility, skidding and swaying of vehicles, less positive steering response, longer stopping distance and broken windshields from flying rocks.

Roadside aesthetics are affected in three principal ways by road dust. Road dust can reduce the enjoyment of life, lower property values and increase cleaning costs.

Road dust may affect vegetation by increasing heat absorption and reducing transpiration causing a heat build up in the leaf.

Soil characteristics such as pH, electrical conductivity and nutrient relationships may be affected by road dust. Positive or negative changes in soil conditions may occur depending on the characteristics of the road dust.

Aquatic systems, specifically plants and fish may be affected by road dust if sufficient amounts are deposited in waterbodies.

ROAD DUST SUPPRESSION

Road dust emissions may be reduced by traffic controls, paving and applications of road stabilizers or dust suppressants.

Traffic controls, such as the lowering of speed limits will reduce road dust generation. Theoretically a 66 percent reduction in the level of dust could be achieved by reducing speed limits from 50 km/hr to 17 km/hr. Traffic controls have no adverse environmental impacts and are cost effective. However, problems with enforcement and increased social costs - specifically increased travel time, must be considered before adoption for road dust control.

There are three general types of pavement:

- o bituminous concrete;
- o concrete; and
- o chip seals.

Paving minor roads is the most effective method of road dust control, however, its high initial cost precludes its use in most cases. The environmental impact of paving materials themselves is minor, however, the impact of the paving operation may be great.

Road dust control on minor roads is usually achieved through the use of dust suppressants. There are four major types of suppressants on the market today:

- o water and wetting agents;
- o deliquescent and hygroscopic chemicals;
- o organic non-bituminous binders; and
- o petroleum based suppressants.

Water may be applied alone or in association with wetting agents. Water and wetting agents are usually applied for short term suppression purposes at construction sites or mine access roads. Wetting agents

extend the life of the water suppressant. The use of water and wetting agents results in no adverse environmental impacts, although salt water application may have environmental consequences similar to calcium chloride. The frequency of application depends primarily upon local climatic conditions, and the amount of water applied is approximately 6000 litres per kilometre. Costs of watering roads in northern and western Canada range from $17,000 to $40,000 per kilometre per year, depending on the availability of water and the wetting agent used.

Deliquescent and hygroscopic chemicals attract water from the atmosphere to bind road particles together. Calcium chloride is the most widely used deliquescent chemical in use in nothern and western Canada. Calcium chloride may adversely affect water supplies, plants and aquatic species if not applied in a prudent manner. Application rates are usually 1.5 to 2.0 litres per square metre at a cost of $3000 to $5000 per kilometre. Calcium chloride has been shown to be most effective in areas where relative humidities exceed 30 percent.

Lignosulfonates, are organic non-bituminous binders, whose lignin fraction serves as a glue to bind dust particles. Lignosulfonates have been shown to be moderately toxic towards rainbow trout and aquatic plant life. Application of lignosulfonates are generally in the 2.0 litre per square metre range at a cost of $1500 to $5000 per kilometre depending on distance from the suppressant source. Studies in northern and western Canada have shown that lignosulfonates are an effective dust palliative lasting two to three months.

DC-M18 is a non-toxic, biodegradable enzyme-based biochemical in solution with a very heavy organic polymer and a wetting agent. Application of DC-M18 is with water at a rate of 140 to 170 litres of suppressant per kilometre. The cost of the suppressant is two to three dollars per litre depending on order size.

Petroleum based suppressants include commercially available products as well as used lubricating oil. Depending on the "curing" time of the

suppressant the mechanism of suppression may be a cementing or a coating with a fluid film. Petroleum based suppressants may affect vegetation, soils and water supplies if not properly applied. Application rates and cost vary with the suppressant applied. Petroleum based suppressants are an effective dust control alternative.

WASTES SUITABLE FOR ROAD DUST SUPPRESSION

The utilization of environmentally safe waste materials for suppression is preferable to virgin material use on conservation grounds. Waste materials which have been used for dust suppression in the past are lignosulfonates, used lubricating oil, salt brines and whey. Based on characteristics exhibited by suppressants in use today, waste materials which may be considered for suppression purposes in the future include fly ash, hydrogenated tallow, rubber latex, modified sulphur compounds, calcium or magnesium carbonate and magnesium chloride.

ROAD DUST SUPPRESSION IN NORTHERN AND WESTERN CANADA

Provincial, territorial, municipal and county authorities in northern and western Canada are primarily responsible for issuing guidelines and administering road dust control programs. Decisions on types of suppressants, application rates and expenditures are made by officials within the above authorities. The most popular suppressants in use are calcium chloride, calcium lignosulfonate and petroleum based suppressants such as used oil. The degree of success experienced with individual suppressant was found to depend on the local conditions.

REPORT RECOMMENDATIONS

This report provides background information on road dust generation and impact and reviews methods by which road dust may be suppressed. This information should be distributed to all road dust suppression decision-making authorities in northern and western Canada. In addition, infor-

mation deficiencies identified in the report should be addressed. The following six studies are recommended:

1. A study to identify the environmental impact of road dust suppressants should be undertaken. Specific consideration should be given to long term exposure of natural systems to low concentration levels of suppressants.

2. A study to identify dust suppressant alternatives for northern and western Canada is required. Specific consideration should be given to waste material utilization.

3. A detailed study identifying and quantifying the effects of road dust on the roadside environment is required. This would enable authorities to decide whether road dust suppression is required in certain areas.

4. A study determining the relationship between dust pollution and control expenditures should be undertaken. This relationship would enable authorities to priorize control programs.

5. A field oriented study to quantify residual effectiveness of dust suppressants from one application season to the next is required.

6. Research should be undertaken to identify suppressants suitable for use on sandy subgrades. At present only cost prohibitive alternatives for minor roads are available.

ROAD DUST SUPPRESSION IN NORTHERN AND WESTERN CANADA

REVIEW OF ALTERNATIVES AND EXISTING PRACTICES

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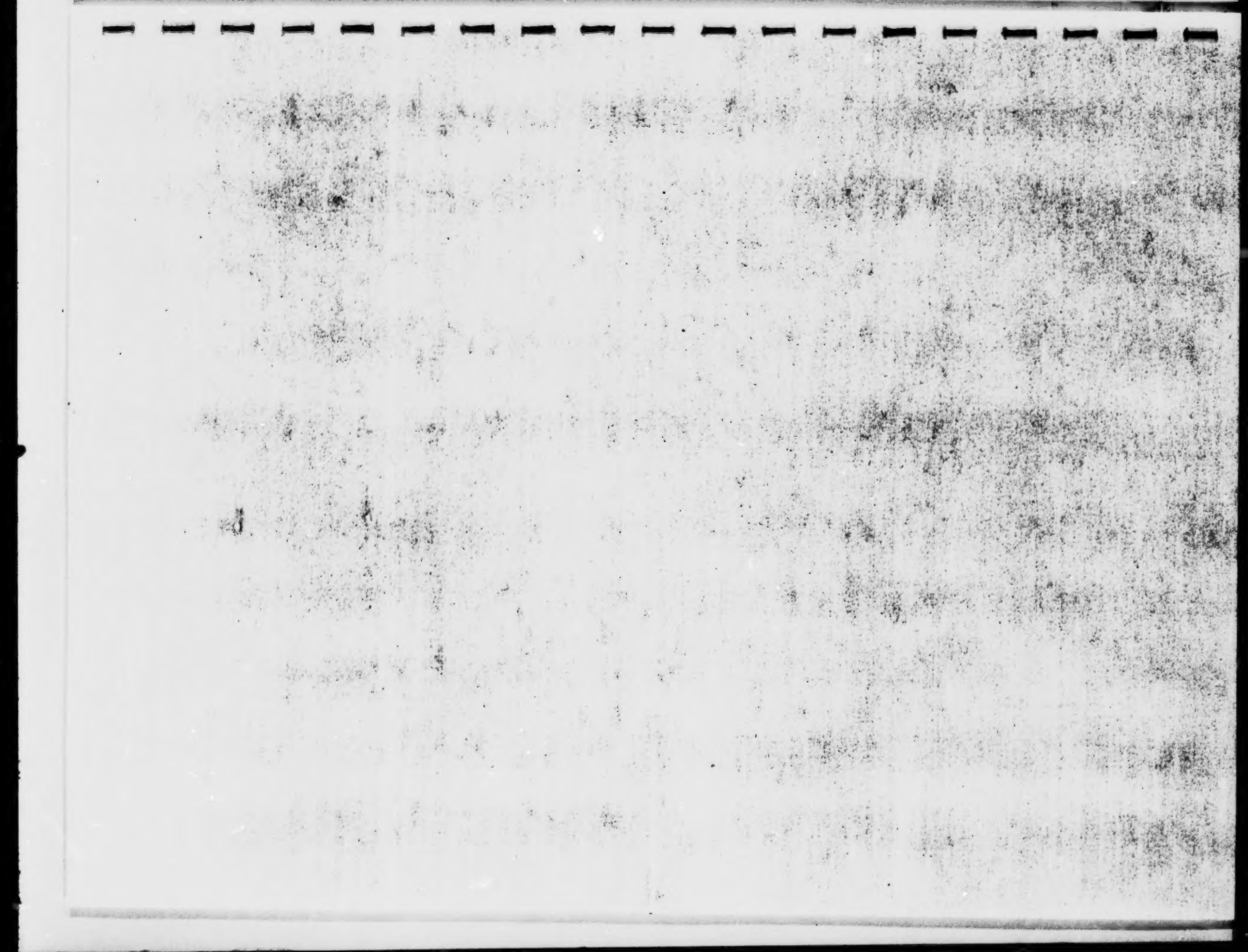
CHAPTER 1

OBJECTIVES AND METHODS



CHAPTER 1

OBJECTIVES AND METHODS

1.1 INTRODUCTION

The spreading of various substances on northern and western Canadian unpaved roads for dust suppression during the spring and summer months is a longstanding practice. Approximately 80 percent of roads owned or maintained by government and private interests in northern and western Canada are unpaved and are potential dust generators (Bell 1976; Statistics Canada 1973). Approximately 10 million dollars were spent in 1981 on road dust suppression in western Canada.

The purpose of this study is to identify the environmental implications of dust palliation and to place them in context with the technical and economic aspects of suppression programs. This study will complement the hundreds of studies conducted to measure the effectiveness of dust suppression materials on roads. This study has been commissioned by the Federal Environmental Protection Service in association with the Environment Departments of British Columbia, Alberta, Manitoba and the Northwest Territories. The information compiled will assist in developing environmentally, technically and economically sound road dust control programs.

1.2 OBJECTIVES

The major objectives of this study are:

- to examine the technical aspects of road dust;
- to assess the effect of road dust on the environment;
- to review available road dust suppressants from a technical, environmental and economic perspective;
- to review existing road dust suppression practices in northern and western Canada;

- o to identify research and development needs; and
- o to prepare a reference document on dust suppression that may be used by federal, provincial, territorial and municipal authorities in planning short-or long-term suppression programs.

1.3 METHODS

To meet the stated objectives of the study, a review of existing information was undertaken. Original research was not performed. Four primary sources were solicited for road dust suppression information:

- o established data bases;
- o government agencies;
- o industry; and
- o other knowledgeable individuals.

Information collected includes published and unpublished reports, raw data and personal insights and experience.

Established Data Bases The primary source of information for this study was the on-line computer search of established data bases. The ORBIT and CAN/OLE information retrieval systems were utilized. The data bases searched and the keywords utilized in the search are provided in Table 1-1.

Government Agencies Federal, provincial, territorial and municipal governments were contacted by mail, personal interview or telephone. The primary departments approached included Transportation, Highways, Municipal Engineering and Environment. Specific contacts and agencies approached are listed in Section 8.5.

Industry Industry information sources were contacted by telephone or personally interviewed. Two types of industry information were solicited. The first was information from companies which manufacture dust control agents and market them commercially. The second industry source

Table 1-1

Data Bases and Keywords Utilized During On-Line Computer Searchs

Data Bases Searched CAN/OLE or ORBIT	
1. Apilit	6. Enviroline
2. Biosis 80	7. Environment Canada Departmental Library
3. Compendex	8. Forest
4. Directory of Federally Supported Research in Universities	9. NTIS
5. Engineering Index	10. Paperchem

Keywords	
1. Asphalt	24. Leachates
2. Asphalt binder #	25. Lignosulfonate #
3. Asphalt Cutback #	26. Lignosulphonate #
4. Asphalt Emulsion #	27. Oil
5. Biodegradation	28. Oiling
6. Biomagnification	29. PCB #
7. Bituminous	30. Pollution
8. Bituminous Emulsion	31. Polychlorinated Biphenyl #
9. Bunker Oil	32. Recycl:
10. By-Product #	33. Recycled Oil
11. Calcium Chloride	34. Road:
12. Chemicals	35. Runoff
13. Chemistry	36. Safety
14. Dust	37. Sodium Chloride
15. Dust control	38. Stabiliz:
16. Dust Palliat:	39. Suppress:
17. Dust Suppress:	40. Toxicity
18. Engineering	41. Transportation
19. Environmental	42. Used Oil
20. Environmental Impact #	43. Visibility
21. Highway #	44. Waste
22. Highway Dust	45. Waste Material
23. Impact #	46. Waste Oil

= Any Letter

: = Any Suffix

was those companies, such as mining and pulp and paper companies, required to use dust suppressants in their operations. Specific contacts made are listed in Section 8.5.

Knowledgeable Individuals Transportation association representatives, university professors and related professionals were contacted by telephone. Section 8.5 lists individuals contacted.

1.4 REPORT ORGANIZATION

The overall report consists of two self-supporting documents. This volume contains a discussion of the technical and environmental implications of road dust and identifies dust suppressants which are or could be used for palliative purposes in the study region. The second volume is a manual of recommended practices and focusses on the practical aspects of road dust suppression discussing selection, application and testing of suppressants. All costs presented in the report are in 1981 Canadian dollars, unless otherwise specified.

1.5 REPORT APPLICATION

Use of Report. This volume is a review of the theoretical aspects of road dust generation and suppression and provides the basis upon which the manual of recommended procedures is built. The overall report is a reference document that summarizes the technical, environmental and economic aspects of road dust suppression for federal, provincial, territorial and municipal officials.

Data Limitations The information search conducted for this study is one of the most comprehensive to date on road dust suppression in northern and western Canada. However, the availability and quality of information for the topics covered in this report varied considerably. Information variance and available time has directly affected topic analysis. Every effort has been made to flag data limitations and deficiencies where they occur.

CHAPTER 2

ROAD DUST CHARACTERISTICS

CHAPTER 2

ROAD DUST CHARACTERISTICS

2.1 ROAD DUST DEFINITION

A search of the literature revealed that there is no universally accepted definition for road dust. Researchers have had to define road dust on a report-specific basis. For the purposes of this report, road dust is defined as a particulate emission which results from the detachment and relocation of road aggregate particles, through the abrasive action of traffic. Lillis and Young (1975) refer to such emissions as "fugitive" dust.

2.2 MECHANICS OF ROAD DUST GENERATION

Traffic tends to reduce both the clay content (which aids in binding together the larger particles) and the moisture content of the road surface, leaving it drier and more friable (Murphy 1967). Under these conditions, road dust may be generated by a passing vehicle. The emissions are generated by :

- o vortex entrainment;
- o slippage entrainment; and
- o saltation and creep of larger particles.

The overall emissions due to vehicular traffic are the sum of emissions from the above three sources.

2.2.1 Vortex Entrainment

As a vehicle passes over an unpaved road, air compression and expansion result in a draft that "pumps" dust into the air. A quantitative expression for estimating dust generation from vortex entrainment was not found in the literature. However, the Monsanto Research Corporation

(1981) has identified an equation developed by the Pittsburgh Mining and Safety Center (Singer et al. 1972) which could be used for estimating the dust contribution of vortex entrainment. The equation was developed for wind erosion from flat coal storage piles, and is as follows:

$$E_c = \frac{0.336V^3P^2S^{0.35}}{(PE)^2} \qquad (1)$$

where E_C = emissions due to wind erosion of a coal pile or vortex entrained dust generation.

Coal Variables

V = wind speed in m/s

P = bulk density in g/cm^3

S = surface area in m^2

PE = precipitation-evaporation index of study area

Vortex Entrainment Variables

V = vehicle speed in m/s

P = soil bulk density of road in g/cm^3

S = width of vehicular air displacement in m^2

PE = precipitation-evaporation index of study area

2.2.2 Slippage Entrainment

Slippage between the road and tire of the vehicle is the major contributor to road dust generation. The force of tires upon the soil grains of the road surface acts as an erosive agent (Murphy 1967). The resultant slippage between tire and road surface will suspend the material in the slippage zone. The mechanics of slippage entrainment may be considered to occur in three phases:

- phase 1 - as the wheel approaches, the particle is forced forward and out with an abrading effect (at this point vortex entrainment is also involved);

- o phase 2 - when the vehicle is directly overhead, the particle is forced downward with a crushing effect; and
- o phase 3 - when the vehicle leaves, the particle is forced backward and out with an abrading effect (saltation and creep of aggregate also involved here).

Figure 2-1 illustrates the three phases associated with slippage entrainment.

The resistance of a soil to vehicular wearing action depends upon the bond between the soil particles. If the bond is broken, but sufficient moisture is present, it will re-establish as the wheel moves away; however, as the soil moisture content decreases, a point is reached where the bond remains broken and dust is created (Murphy 1967).

Figure 2-2 illustrates the initial detachment phase of the slippage entrainment. As a tire passes over a soil particle, the effect of the pressure and rotational movement picks up the particle and throws it into the atmosphere at a variety of angles depending upon the input torque of the tire. The range of angles has been measured to be between 0° and 60° (Wismer 1966).

Cowherd (1974) has determined that slippage entrainment emissions from unpaved roads can be related to vehicle speed and soil siltiness, as shown in the following equation:

$$E=0.23(S)^{\left(\frac{V}{13}\right)}\left(\frac{365-R}{365}\right) \qquad (2)$$

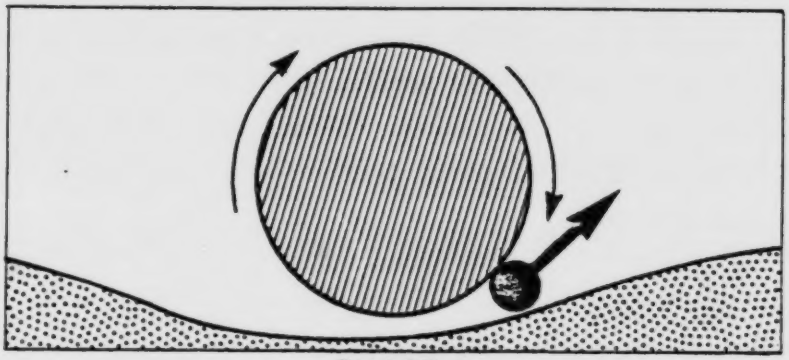
where E = emissions in gram per vehicle - metre travelled

R = days of rainfall over 0.03 cm per year

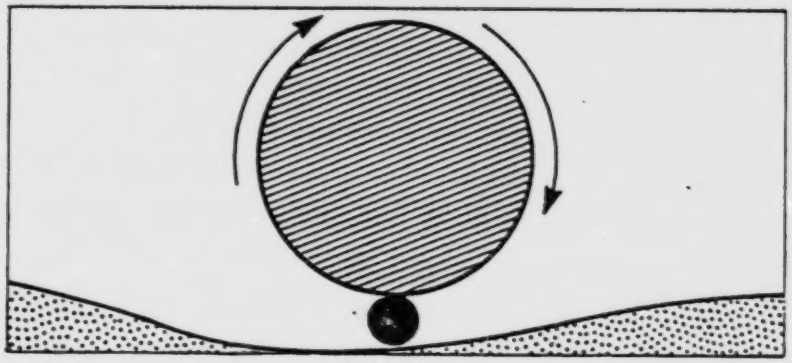
V = vehicle speed in m/s

S = soil siltiness in percent

Soil siltiness is a function of particle size distribution and affects the depth of soil distribution in the slippage zone. Vehicle speed also



PHASE 1



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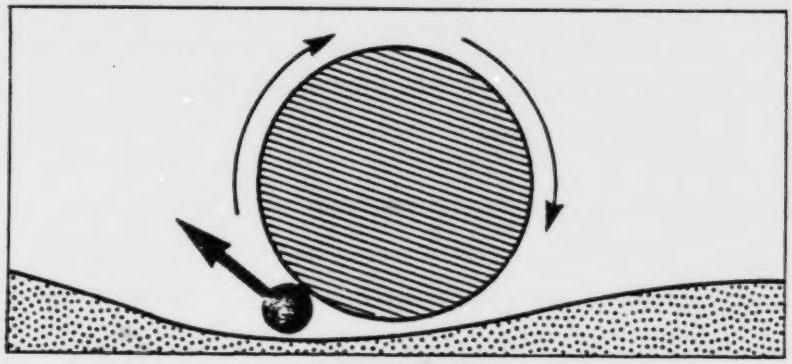

PHASE 3

FIGURE 2-1

ACTION OF TIRES ON SOIL PARTICLE

(Sultan 1974)

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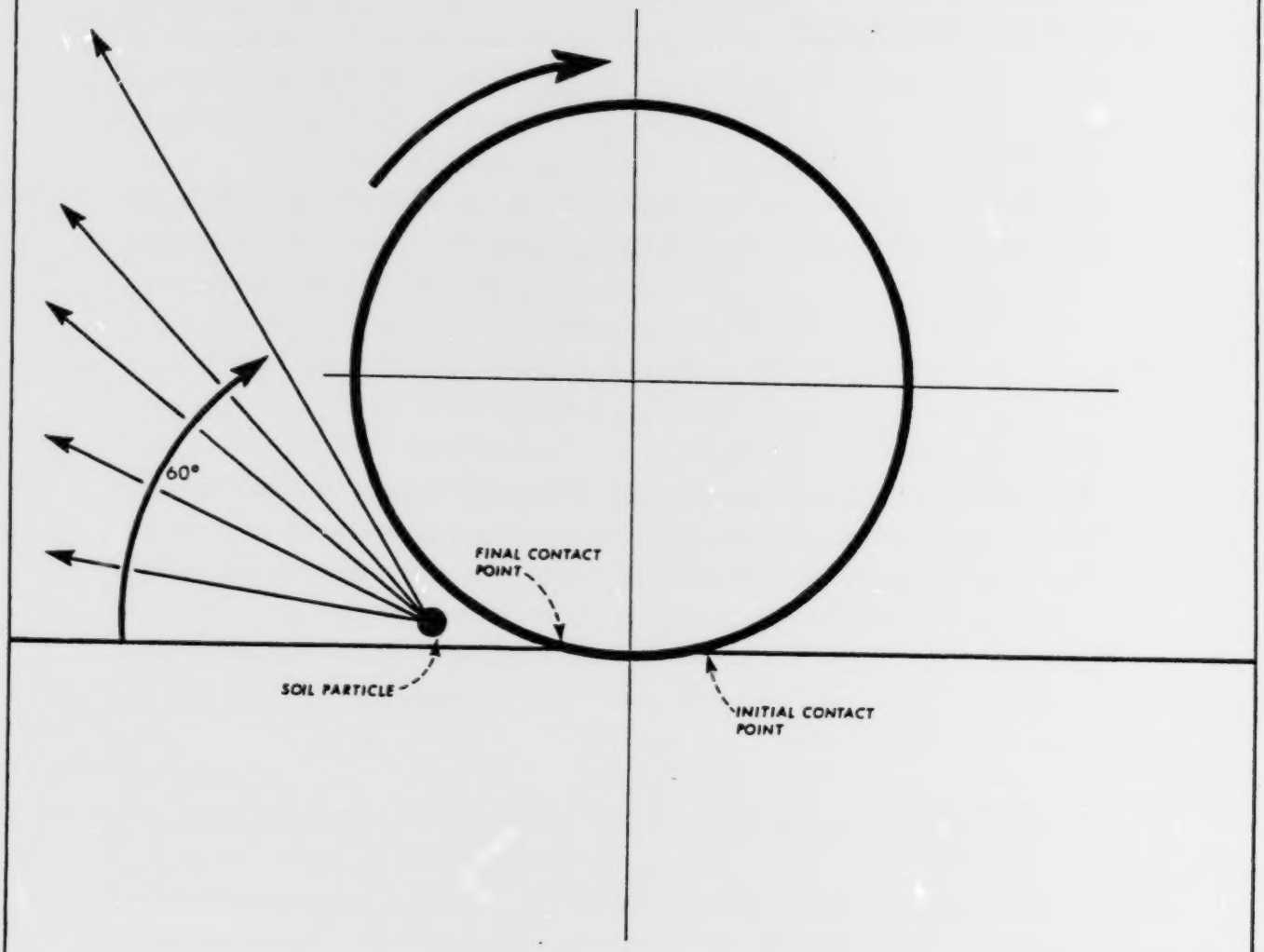

FIGURE 2-2

MICROSOPIC VIEW OF TIRE ON SOIL GRAIN

(After Sultan, 1974)

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Techman Engineering Ltd.

contributes to the depth of soil displacement (Monsanto Research Corporation 1981). A general model for slippage entrainment has been developed by the Monsanto Research Corporation and may take the form of the following equation:

$$Q_B=(k_1)\ \frac{LWZP}{T}=k_1VWZp \qquad (3)$$

where k_1 = emissions constant

L = length of vehicle travel

W = width of tires

Z = thickness of soil disturbed

P = soil density

T = time of travel

V = vehicle speed, L/T

The Monsanto Research Corporation (1981) has estimated that slippage entrainment (including saltation and creep of aggregate) is responsible for approximately 99 percent of dust generated per vehicle meter travelled. Vortex entrainment is responsible for the remaining one percent. The above estimates were based on average road conditions of 12 percent silt and 120 "wet" days (days of rainfall over .03 cm) per year.

2.2.3 Saltation and Creep of Large Particles

Large particles (>10 microns) suspended by slippage entrainment may result in transport via saltation and surface creep. Saltation refers to the bouncing and jumping motion of aggregate particles. The bouncing particles strike the ground at shallow angles (10 to 16 degrees) and, either bounce into the air again or dislodge other grains. Most saltation occurs within a few centimetres of the ground. By force of impact, saltating grains can move particles more than 200 times their own weight. Soil that is moved by saltation consists mainly of grains 0.05 mm to .5 mm in diameter (Canessa 1977).

Surface creep refers to the slow movement of the road surface caused primarily by the direct impact of saltating grains on particles that are too heavy to be dislodged and bounced into the air (Canessa 1977). Such particles vary in diameter from 0.5 to 1 mm. Most of the kinetic energy in the surface creep phenomenon is supplied by impact of grains moving in saltation (Canessa 1977). Figure 2-3 illustrates aggregate movement by saltation and surface creep.

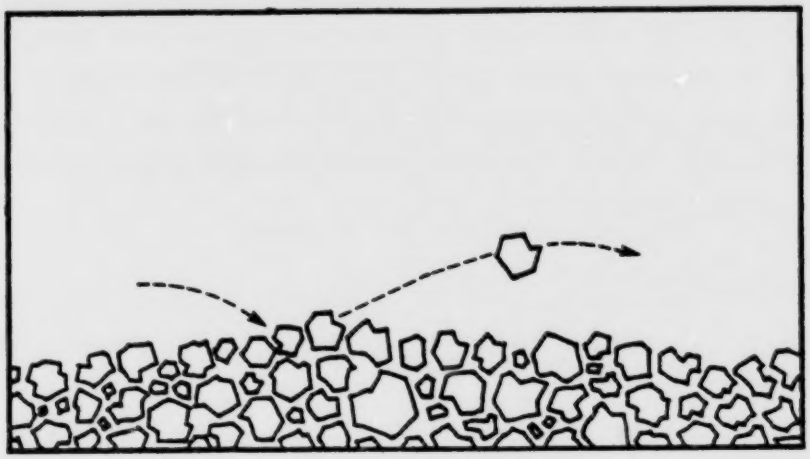
The emissions constant k_1 in Equation 3 should include the contribution of saltation and surface creep in its derivation (Monsanto Research Corporation 1981).

2.3 FACTORS AFFECTING THE AMOUNT OF ROAD DUST EMISSIONS

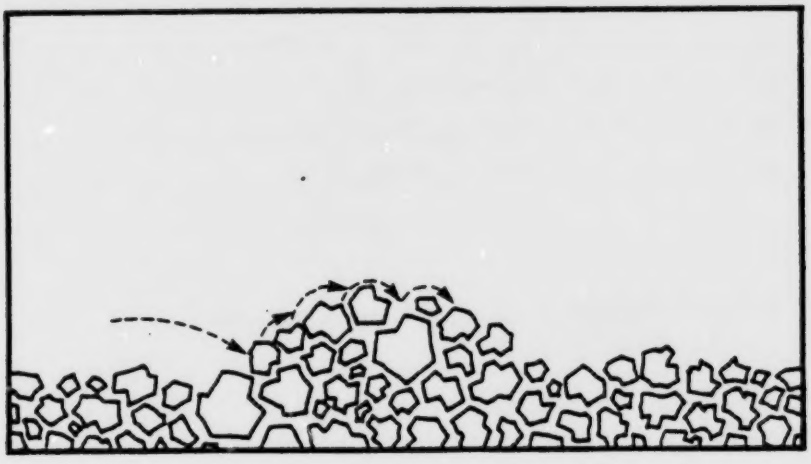
Dust emissions from unpaved roads are generated by slippage entrainment, vortex entrainment and saltation and creep of the larger particles. These mechanisms, as pointed out in the previous sections, are related to air turbulence and the mechanical forces of tires on the road surface. There are several factors which greatly affect the rate at which dust emissions are generated. These are:

- vehicle speed ;
- number of wheels/vehicle;
- particle size distribution;
- surface moisture index;
- vehicle weight;
- vehicle cross section;
- tire width;
- tire design;
- length of unpaved road; and
- design of roadway.

The above factors can be used to relate dependent and independent variables in equation form.



Saltation of Loose Aggregate



Surface Creep of Loose Aggregate

FIGURE 2-3

GENERATION OF ROAD DUST BY SALTATION AND SURFACE CREEP OF LOOSE AGGREGATE

(Conesa 1977)

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2.3.1 Vehicle Speed

Table 2-1 lists results of various tests conducted on emissions from unpaved roads. The study, conducted by the Puget Sound Air Pollution Control Agency, can be used to predict a mathematical relationship for the emission of respirable particles from unpaved roads. The results show that emissions of particles less than 2 microns in diameter are proportional to the vehicle speed (V), and those less than 10 microns in diameter are proportional to the square of the vehicle speed (Monsanto Research Corporation 1981). Figure 2-4 graphically illustrates the relationship of particle size to vehicle velocity. Based on the findings of the Puget Sound study, one could expect emissions of respirable particles (less than 10 microns) to be proportional to (aV^2+bV) where a and b are constants. Thus:

$$E_u=(aV^2+bV) \quad (4)$$

where E_u = emissions, g/vehicle

V = vehicle speed

a,b = constants (Midwest Rsearch Institute 1981)

2.3.2 Number of Wheels

A vehicle moving on an unpaved road generates dust in proportion to the number of its wheels. Thus:

$$E_u::N \quad (5)$$

E_u = emissions, g/vehicle

where N = number of wheels per vehicle (Monsanto Research Corporation 1981).

Studies performed by Ekse (1965) concluded that dual tires have much higher loosening effect on straight roadways than do wide single tires under the same loading. On the other hand, Ekse (1965) observed that wide single tires may do more damage to curved road sections.

Table 2.1

Test Results of Unpaved Road Emissions (Monsanto Research Corporation, 1981)

Investigator	Sampling site	Type of road	Vehicle Speed km/hr	Emission factor g/veh-m	Particle size distribution, μm
Anderson, C. (b)	Bernalillo County, N.M.	Dirt	48	0.14-0.20	— (a)
School of Engineering, University of New Mexico	University of N.M.	Dirt	40	0.26	< 6
				0.01	< 3
Pedco-Environmental Specialists, Inc. (c)	Santa Fe, CAL	Dirt	24	0.19	— (a)
			40	0.28	— (a)
			56	0.56	— (a)
			64	0.99	— (a)
Engineering Research Institute, Iowa State University	Powshiek County, IA	Dirt	—	1.55	— (a)
Puget Sound Air Pollution Control Agency (d)	Duwamich Valley, WA	Gravel	16	0.62	— (a)
				0.12	— (a)
				0.03	> 2
			32	2.40	— (a)
				2.48	— (a)
				0.65	— (a)
				0.68	— (a)
				0.08	< 2
			48	3.92	— (a)
				1.47	< 10
				0.12	< 2
Midwest Research Institute (e)	Franklin County, KS	Gravel	48	1.135	> 30
				0.950	2 to 30
				0.770	< 2
		Gravel	48	1.0	> 10
				1.05	> 30
				0.882	2 to 30
		Gravel	64	1.705	< 30
				1.22	2 to 30
				1.025	< 2
	Morton County, KS	Dirt	48	2.33	> 30
				1.25	2 to 30
				1.05	< 2
		Dirt	64	0.597	> 30
				0.597	2 to 30
				0.512	< 2
	Wallace County, KS	Dirt	48	6.82	30
				5.35	2 to 30
				3.72	< 2

(a) No designated size distribution.

(b) Anderson, C. Air Pollution from Dusty Roads. In: Proceedings of the 1971 Highway Engineering Conference, Bulletin No. 44-NMSU-EES-44-71, Las Cruces, New Mexico, 1971. 12 pp.

(c) Investigation of Fugitive Dust Sources, Emissions, and Control. Contract 68-02-0044, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, May 1973. 152 pp.

(d) Roberts, J.W., A.T. Rossano, P.T. Bosserman, G.C. Hofer, and H.A. Watters. The Measurement, Cost and Control of Traffic, Dust and Gravel Roads in Seattle's Duwamish Valley. In: Proceedings of the Annual Meeting of the Pacific Northwest International Section of the Air Pollution Control Association, Paper No. AP-72-5, Eugene, Oregon, 1972. 10 pp.

(e) Cowherd, J., Jr., K. Axetell, Jr., C. Guenther, F. Bennett, and G. Jutze. Development of Emission Factors for Fugitive Dust Sources. EPA-450/3-74-037, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, June 1974. 172 pp.

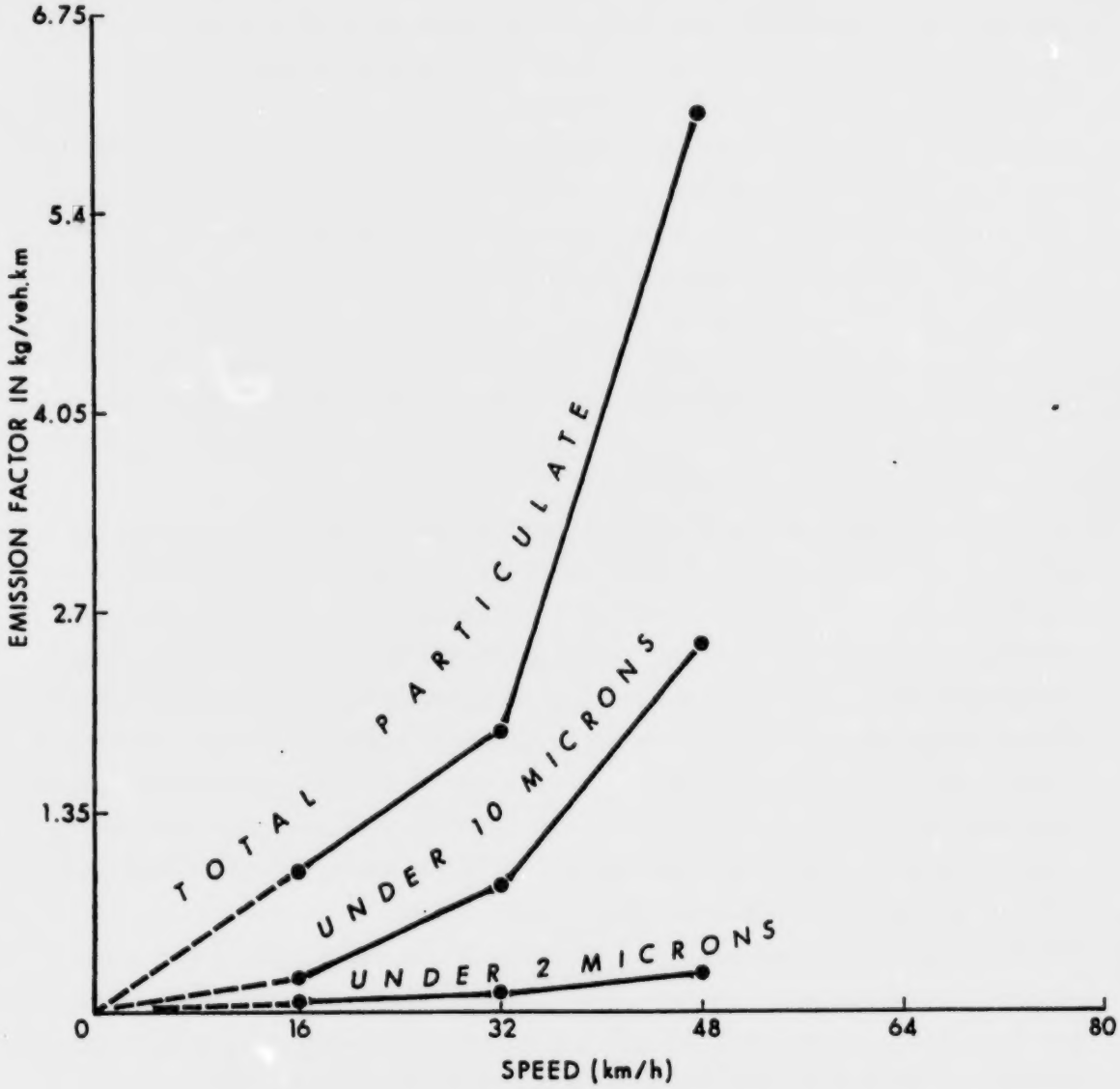

FIGURE 2-4

RELATION BETWEEN SPEED AND EMISSIONS BY PARTICLE SIZE FROM A GRAVEL ROAD

(Roberts 1974)

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2.3.3 Particle Size Distribution of the Road Surface Material

Wind tunnel studies and open-field measurements show that the proportion of movement of particles by suspension is approximately equal to the proportion of particles less than 100 microns found in the soil (Chepil in Monsanto Research Corporation 1981). Hence the relationship is:

$$E_u :: P \qquad (6)$$

where Eu = vehicle emissions

P = percent of particles (less than 100 um) in the road surface material (0 cm to 10 cm depth).

The best road surface is usually a well graded soil composed of larger particles that resist abrasion along with smaller particles to bind them together.

2.3.4 Surface Moisture

Surface moisture has an important influence on soil strength. As particle moisture increases, the cohesive force between particles increases and the rate of soil entrainment decreases (Monsanto Research Corporation 1981). The rate of soil movement varies inversely with the square of its moisture content (Chepil et al. 1962). However, soil surface moisture is assumed to be proportional to the Thornwaite Precipitation-Evaporation (PE) Index. The PE Index is determined from the total annual rainfall and mean annual temperature (Thornwaite 1981). Thus:

$$E_u :: \frac{1}{(PE)^2} \qquad (7)$$

2.3.5 Vehicle Weight and Vehicle Cross Section

No quantitative data describing the effect of vehicle weight and vehicle cross section on unpaved road emissions was found in the literature.

2.3.6 Tire Width and Tire Design

No quantitative data describing the effect of tire width and design on unpaved road emissions was found in the literature.

2.3.7 Length of Unpaved Road

A vehicle generates dust in proportion to the length of the unpaved road, thus:

$$E_u :: L \qquad (8)$$

where L = the length of the unpaved road (Midwest Research Institute 1981).

2.3.8 Design of Roadway

No quantitative data describing the effect of roadway design was found in the literature. Sultan (1974) has stated qualitatively that roadway geometrics, such as variations in vertical and horizontal alignment, cause acceleration and deceleration of the vehicle. This results in larger forces at the road surface than are encountered on straight level roads. The centrifugal forces in horizontal curves also cause erosion and dust generation.

2.4 ROAD DUST COMPOSITION

Road dust, once suspended, is composed of a wide variety of particulates which may have diverse physical and chemical characteristics. The primary factor affecting particulate characteristics is the composition of the road surface aggregate. In northern and western Canada a variety of minerals is available for road surface aggregate. The site specifity of aggregate use precludes a detailed discussion within this report. However, a general discussion of the physical and chemical characteristics of road dust is provided in the following sections.

2.5 ROAD AGGREGATE COMPOSITION

Roads are constructed primarily from:

- o naturally occuring aggregate materials; and
- o crushed rock.

The rock is crushed to meet screen-size requirements for surface-finishing. In northern and western Canada, road aggregate is derived primarily from four classes of material:

- o glaciofluvial sand and gravel;
- o crystalline rocks;
- o sedimentary rocks, primarly carbonates; and
- o glacial till.

The dust generated by vehicular traffic on the aggregate materials can be expected to exhibit relatively constant mineral components.

Tamm (1959) and Parker (1978) analyzed dust which had collected on needles and leaves of trees adjacent to unpaved roadways. Tamm's research was conducted in Sweden, while Parker's was conducted in northern Alberta. The results of both studies indicated that concentrations of calcium, sodium, magnesium, potassium, phosphorous and nitrate were present. The contributory source of these elements was concluded to be the unpaved roadway.

2.6 PHYSICAL CHARACTERISTICS OF ROAD DUST

Roberts et al. (1973) has identified three important sizes of road dust:

- o > 10 microns-represents large particles suspended by a moving vehicle, the largest of which are capable of damaging or breaking windshield, headlights or automobile trim;

- o > 2 microns but < 10 microns-represents visible suspended dust particulates; and
- o < 2 microns-comprises particulates which have the potential for maximum deposition in the lungs.

Hoover (1981) has shown that the larger particulates (> 10 microns) will be airborne only short distances from their source, while very fine particulates (such as silt, clay and colloidal sizes) may be airborne over extremely long distances. Hoover (1981) also reports that masses of finer particles generally show increased surface area coupled with larger potential for physico-chemical surface activity. This results in:

- o electric potential at the faces of the particle; and
- o capillary attraction between two or more particles due to minute quantities of water (sometimes termed capillary cohesion).

However, even minor differences in mineralogical composition between road materials will result in variations in physico-chemical surface-chemical interactions exhibited by these road materials.

2.7 DEPOSITION OF ROAD DUST PARTICLES

Soon after the road particles are suspended (via the suspension techniques identified earlier), the process of deposition begins. Deposition depends primarily on the size of the particles involved; the larger the particle, the faster it will fall to the ground. The smallest particles travel the farthest from their original locations. Because of large forces produced by passing vehicles, particles as large as 6.5 cm in diameter have been recorded as becoming airborne (Sultan 1974).

In Iowa, Hoover (1971) conducted a road dust deposition study to quantify the amount of road dust which accumulates at specified distances from the road centre line. Road dust collectors were placed

adjacent to a roadway whose average daily traffic count was 110 vehicles. The study found that, depending on the prevailing wind conditions, slightly higher dust quantities were found immediately adjacent to one side or the other of the roadway. In addition, the results indicated:

- deposition amounts were constant from approximately 30 metres to 90 metres from the roadway centre line, regardless of the wind direction (Fig. 2-5); and

- the bulk of dustfall from a roadway is within 30 metres of the centre line (Fig. 2-5).

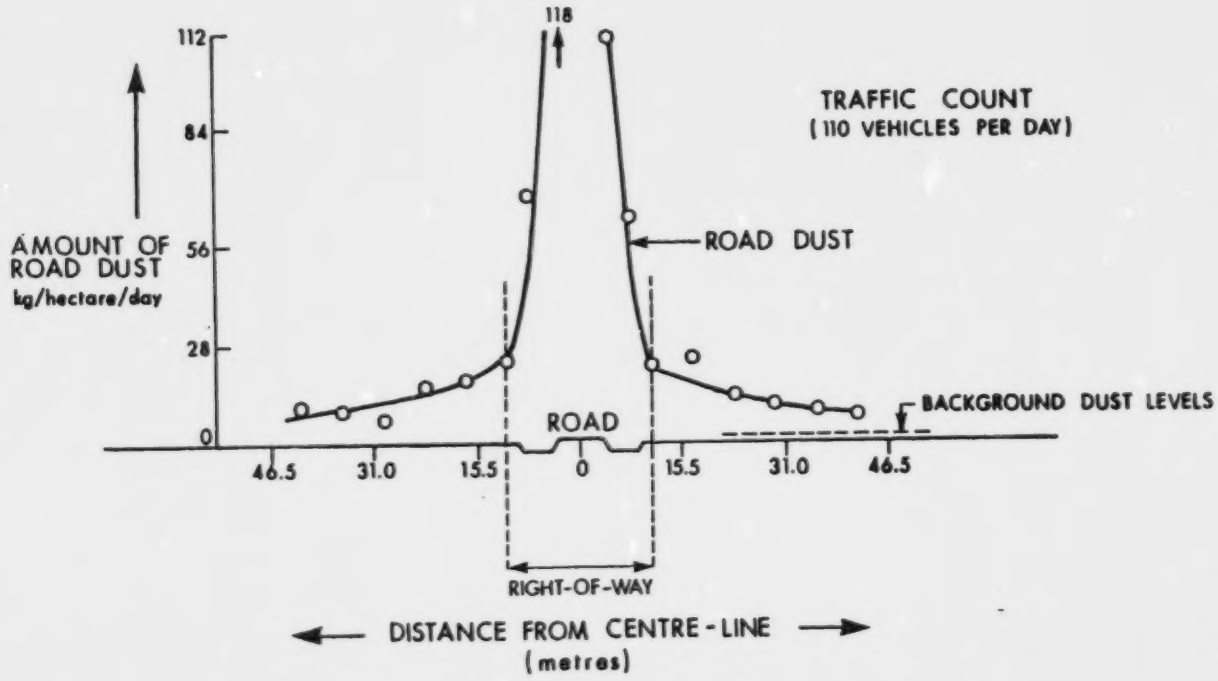

FIGURE 2-5

AMOUNT OF DAILY ROAD DUST ACCUMULATION vs DISTANCE FROM CENTRE-LINE

(After Hoover 1971)

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CHAPTER 3

IMPACTS OF ROAD DUST

CHAPTER 3

IMPACTS OF ROAD DUST

3.1 INTRODUCTION

Although road dust has long been considered an environmental hazard and social irritation, these factors have not been well documented in the literature. Historically, road dust control programs have been empirical in nature. The purpose of this chapter is to place the road dust problem into proper perspective and to review the available literature on road dust impacts.

3.2 ROAD DUST GENERATION IN PERSPECTIVE

A nationally conducted Canadian inventory of air pollution emissions from all sources (industrial, as well as natural) indicated that particulates are responsible for 7.6 percent of total emissions in Canada. Of this 7.6 percent, industry was estimated to contribute 4.4 percent or 1.2×10^6 tonnes in 1970 and natural sources, including unpaved roads, the balance or 8.7×10^5 tonnes (Environment Canada in Bell 1976).

A recent Environmental Protection Agency report documented emission rate estimates of particulates from open sources in the United States (Cooper et al. 1979). The study was based on emissions and sources noted within the literature. The following are estimated rates of emission in millions of tonnes per year:

- unpaved roads - 270
- construction activities - 27
- wind erosion - 28
- paved roads - 7
- wildfires - 2
- agriculture tilling - 2
- mineral extraction - 2

The EPA study concluded that the major contributor to total suspended particulates (TSP) was soil-like material, with unpaved roads, especially in cities, and construction activities as primary sources.

Hoover (1973) estimated that for every vehicle which travels one kilometer of unpaved roadway, once a day, every day of the year, .002 kg/m^2 of dust is deposited along a 300 metre wide corridor centered on the road. This is comparable to the average ambient dustfall level of approximately .0002 kg/m^2/day.

3.3 ENVIRONMENTAL AND SOCIAL IMPACTS

There is a dearth of literature addressing atmospheric pollution by road dust. The information that is available may be divided into the following impact areas:

- safety;
- aesthetics;
- health;
- vegetation;
- soils; and
- aquatic resources.

The findings of the information reviewed are presented in the following sections.

3.3.1 Safety

Unpaved road surfaces have a greater accident potential than those with a paved surface. Loose surface aggregate results in loss of visibility, skidding and swaying of vehicles, less positive steering response, longer stopping distance and broken windshields from flying rocks. In the United States, the fatality rate on unpaved roads is 2.3 times the rate of the paved primary system (Hoover 1971). In 1980, Alberta recorded 3 fatalities and 42 injuries in accidents which occurred under

dusty conditions (Alberta Transportation 1982). Accidents attributable to road dust were not confirmed for Manitoba, British Columbia and the Northwest Territories.

Recognition of accident potential from dusty roads in the United States' mining industry has resulted in Mine Safety and Health Administration regulations. The regulations require haul roads to be treated to alleviate dust generation (Williams 1979).

3.3.2 Aesthetics

Dust originating from vehicle travel over unpaved roads produces an immediate visual impact which directly affects residents living adjacent to these dust prone roads. Hoover (1971) states that the concentration of siltsized particles in air 30 metres behind a car moving 56 kilometres per hour on a moderately dusty crushed rock road is about 100 times the pollution concentration of industrial city air. In addition to the visual impacts, Roberts et al. (1979) states that road dust in the air can reduce the enjoyment of life, lower property values and increase cleaning costs.

3.3.3 Health

While dustfall has long been considered a nuisance, several authors have expressed concern for human health with respect to dustfall levels. Battigelli (1969) has documented several hypotheses for the mechanism of particulate-human respiratory system interaction. This work identified the importance of dust particle size. Results have indicated that smaller particles (less than 2 microns) become trapped in the lungs due to the inability of the respiratory system to filter all particulates. These findings concur with a United Nations' study which concluded that particles smaller than 3 microns in diameter have the greatest frequency of being retained in the lungs (United Nations 1979).

3.3.4 Vegetation

The visual effect of road dust on vegetation is primarily related to aesthetics, whereby the normal green colour is shaded by dust coating of the foliage. The presence of dust on the plant foliage surface, however, may have direct bearing on the general well-being of the plant. During periods of high heat stress, a coating of dust on foliage could increase solar heat absorption and reduce transpiration causing a heat build-up in the leaf. The incidence of leaf scorch produced by inability of vegetation to maintain satisfactory leaf temperatures is described by MacBryde et al. (1968). Studies undertaken by Spatt and Miller (1981) along the Alaska Highway illustrate a number of specific effects on sphagnum moss relative to road dustfall. Among these are reduced water content, chlorophyll content and carbon uptake and increased temperature, mineral ion concentration and pH in plant water. The possible implications of these dust effects are loss of the sphagnum vegetation cover with a potential for thaw in the permafrost layer.

The potential for alteration of the vegetation community adjacent to a dusty road is also possible through changes in soil chemistry. Dust collecting on foliage can result in the concentration of mineral and nutrient elements in the soils beneath trees and shrubs. Rainfall which drips from foliage can be substantially enriched in some chemical elements (Hart and Parent (1973); Tamm (1959), Parker (1978)). It is obvious that large concentrations of elements that affect soil pH, electrical conductivity or nutrient relationships can also affect the ecology of the plant community supported by that soil.

3.3.5 Soils

Review of the available literature has not provided information on the effects of direct dustfall on soils adjacent to roads. The effects of indirect dustfall through entrapment on vegetation and removal by precipitation have been identified. The effects on soils have been recognized but not quantified. Tamm (1959) has recognized the small

contribution to the soil of nutrients from dust. Hart and Parent (1973) have confirmed the chemical element enrichment of rainfall washed from foliage. It is therefore possible to conclude that a concentration of ions will occur in the soil beneath the dripline of vegetation. The effect of these ions over the long term can be expected to produce changes to soil pH, electrical conductivity and the balance of exchangeable cations. The effect of these changes on soils may be positive or negative depending on local conditions.

3.3.6 Aquatic Resources

Increased dustfall into water systems will increase sedimentation within those systems. The effects of severe sedimentation on fish are possibly the most visible of all impacts and may include the following:

- a reduction in fish growth rates and condition;
- a reduction of fry hiding and living areas;
- an increase in competition, predation and susceptibility to disease;
- destruction of eggs by sedimentation of spawning grounds (occurs for salmonids when spawning gravel contains more than 15 percent by volume silt and sand, McNeil and Ahnell 1964); and
- abrasion of body surface and gill tissues of fish, with suffocation possible if sediments loads reach 20,000 mg/L (Langer 1975).

CHAPTER 4

ROAD DUST SUPPRESSION ALTERNATIVES

CHAPTER 4

ROAD DUST SUPPRESSION ALTERNATIVES

4.1 INTRODUCTION

The factors which influence dust emissions resulting from vehicular use of unpaved roads (as presented in Section 2.3) include:

- o length of unpaved roads;
- o vehicle speed;
- o vehicle weight;
- o number and design of tires;
- o daily traffic on each road;
- o fines content of the road surface; and
- o climate (number of dry days per year).

Road dust emissions can be reduced by:

- o traffic controls;
- o paving; and
- o application of road stabilizers/dust suppressant.

4.2 TRAFFIC CONTROLS

Road dust emissions generated by vehicles are proportional to vehicle speed (Chapter 2). Thus, lowering the speed limit on an unpaved road will reduce emissions generated by traffic on the road. The number of wheels and weight of a vehicle influence the amount of dust generated to a lesser degree (Chapter 2).

4.2.1 Environmental Considerations

No adverse environmental impacts have been identified in implementing traffic controls.

4.2.2 Effectiveness/Durability

Theoretically, a 66 percent reduction in the level of dust could be achieved solely by reducing speed limits from 50 km/hr to 17 km/hr (Roberts et al. 1979). The actual effectiveness of traffic controls may be less than theoretical estimates because traffic controls depend largely on voluntary compliance by drivers and the degree to which regulations are enforced (Midwest Research Institute 1981).

4.2.3 Costs

The monetary cost of establishing traffic controls are negligible, but the social costs are significant. The social cost is reflected by increased travel time related to the lower speeds. Personal travel time cost in 1977 United States dollars has been estimated to range between $1.68 and $6.57 per hour travelled (Winfrey 1969). Commercial travel time in 1977 United States dollars has been estimated to cost between $7.66 and $17.39 per hour travelled (U.S. Bureau of Census 1977). Therefore, a truck travelling 100 km per day would require one extra hour in transit if speed limits were reduced from 50 km per hour to 35 km per hour. The social cost of that extra hour, for planning purposes, would fall within the range of the dollar figures given above.

4.3 PAVING

The class and frequency of traffic on unpaved roads determines the approach used to control dust generation. Paving of roads usually indicates a high frequency of personal and commercial traffic. Paving includes the use of a variety of surfacing materials. Three general types of pavement are:

- o bituminous concrete;
- o concrete; and
- o chip seals.

4.3.1 Bituminous Concrete and Concrete Surfaces

Roads constructed with these two materials are designed to support heavy traffic. Because of their high initial cost, these pavements are not generally used to surface minor roads. Bituminous concrete is a hot mixture of asphalt and a well-graded aggregate; and concrete is a composite material of cement, water and aggregate. Concrete generally requires less maintenance and is more durable than bituminous surfaces (Midwest Research Institute 1981).

4.3.2 Chip Seal Surfaces

Chip seal surfaces-also called macadam-consist of one to three layers of aggregate and asphalt. The asphalt is sprayed over each aggregate layer, top-dressed with a covering of smaller stones and compacted. Finished chip seals are from one to four centimetres thick.

4.3.2.1 Mechanism

Two types of asphalt are used for chip seal surfaces:

- o emulsified asphalt; and
- o cutback asphalt.

Emulsified asphalts contain an emulsifying agent, water and asphalt. Asphalt emulsions are cured by the evaporation of water from the mixtures. Cutback asphalts are formed by adding various amounts of volatile solvents (up to 30 percent kerosene or naptha) to the bituminous mixture. The asphalt hardens as the solvents evaporate into the atmosphere (Midwest Research Institute 1981).

4.3.2.2 Environmental Considerations

Emulsifying agents are corrosive to the skin and care must be taken when handling these substances. Many of the asphalt emulsions (cationic emulsions) can be applied to wet or dry surfaces and are unlikely to be washed away by sudden rain. Other emulsions (anionic emulsions) can more readily be flushed from roadways by rain into receiving streams. Emulsified products are generally stable, nonvolatile and relatively non-toxic (Midwest Research Institute 1981). The use of cutback asphalts should be avoided because of air pollution considerations and their potential to be highly flammable.

4.3.2.3 Effectiveness/Durability

Chip-sealing of an unpaved road binds the surface material and prevents loose material below the surface from being emitted into the atmosphere. Annual dust control efficiencies of paved surfaces have been estimated to range from 90 to 99.9 percent (Environmental Protection Agency 1979). A typical triple-seal chip surface 3.75 centimetres thick can be expected to serve up to 10 years before additional surface treatment is required in the United States. Single chip seal coats generally require a second chip seal coat after one year and another in approximately five years (Environmental Protection Agency 1977).

4.3.2.4 Costs

Bituminous concrete costs from $34,000 to $63,000/km for a 7.6 centimetres surface over a two-lane area. Costs for the same area for a concrete surface can be up to three times as high. The cost of a single chip seal coat over a crushed stone road base ranges from $3,125 to $5,000/km. A triple coat treatment of three layers of aggregate and asphalt costs from $12,500 to $21,900/km (Midwest Research Institute 1981).

4.4 ROAD STABILIZERS/DUST SUPPRESSANTS

The potential for dust generation on unbound road materials is created when there is a decrease in road material moisture content. The tendency to re-establish bonds between particles decreases until the bond remains broken. At this point the road becomes susceptable to traffic erosion and dust generation. A road stabilizer or dust suppressant is an additive which:

- o through some mechanism maintains road material moisture, thus preserving particle to particle bonds; or
- o "cements" particles together.

The efficiency of any dust suppressant depends upon:

- o soil properties of the road;
- o construction of the road;
- o method and frequency of suppressant application;
- o type and volume of vehicular traffic; and
- o local weather conditions.

Several types of dust suppressants are available. The four primary types which may be used on unpaved roads are:

- o fresh or salt water in combination with wetting agents;
- o deliquescent and hygroscopic chemicals;
- o organic, non-bituminous binders;and
- o petroleum derived binders.

A list of suppressants by type and manufacturer is given in Table 4-1.

Table 4-1

Primary Dust Suppressants in Northern and Western Canada and Suppliers

Suppressant	Trade Names	Manufacturer/Supplier Head Office[1]
WATER AND WETTING AGENTS		
Alchem 8808 (Aliphatic hydrocarbon and surfactant base)	Alchem 8808	Alchem Incorporated Box 5002 Burlington, Ontario (416) 632-8791
DELIQUESCENT AND HYGROSCOPIC CHEMICALS		
Calcium Chloride	Liquid Calcium Chloride-35% Liquid Calcium Chloride-25% Liquid Calcuim Chloride-20% Bulk Flake Calcium Chloride-77%	Allied Chemical Canada Limited 201 City Center Dr. Mississauga, Ontario L5B 2T4 (416) 276-9211
	Liquidow Dowflake Peladow	Dow Chemical Canada Incorporated P.O. Box 1012 Sarnia, Ontario N7T 7K7 (519) 339-3131
	Calcium Chloride	C-I-L Incorporated 90 Sheppard Ave. North York, Ontario M2N 6H2 (416) 229-8843
		Harrisons and Crossfield (Canada) Limited 4 Banigan Dr. Toronto, Ontario M4H 1G1 (416) 425-6500
		Van Waters and Rogers Limited P.O. Box 2009 Vancouver, B.C. V6B 3R2 (604) 273-1441

Table 4-1 (Continued)

Primary Dust Suppressants in Northern and Western Canada and Suppliers

Suppressant	Trade Names	Manufacturer/Supplier Head Office[1]
ORGANIC NON-BITUMINOUS BINDERS		
Calcium Lignosulfonate	M & F Road Stabilizer	MacKenzie & Feimann Limited 311-255 W. First St. North Vancouver, B.C. V7M 3G8 (604) 980-7055
	Lignosite	Van Waters and Rogers Limited P.O. Box 2009 Vancouver, B.C. V6B 3R2 (604) 273-1441
Read Chemicals Lignosulfonate (Solid form to be mixed in with aggregrates)		C-I-L Incorporated 90 Sheppard Ave. E. North York, Ontario M2N 6H2 (416) 229-8843
DC-M18 (Enzyme-based biochemical)	DC-M18	United International Industries Ltd. 5723 Burleigh Crescent, S.E. Calgary, Alberta T2H 1Z7 (403) 253-9291
PETROLEUM BASED SUPPRESSANTS		
Used Oil, Waste Oil	Used Oil Waste Oil Recycled Oil Reclaimed Oil	No contact made (Local (Contractors)
Bunker Oil	Bunker A Bunker B Bunker C	No contact made (Local Suppliers)
DL-10	DL-10 Dust Oil DL-10 Asphalt Emulsion	Pounder Emulsions 806-50th St. E. Saskatoon, Saskatchewan S7K 0X6 (306) 653-0574

Table 4-1 (Continued)

Primary Dust Suppressants in Northern and Western Canada and Suppliers

Suppressant	Trade Names	Manufacturer/Supplier Head Office[1]
Emulsified Asphalt	Emulsified Asphalt Primer	Pounder Emulsions 806-50th St. E. Saskatoon, Saskatchewan S7K 0X6 (306) 653-0574
COHEREX	COHEREX	Witco Chemical Canada Limited 2200 Yonge St. Toronto, Ontario M4S 2C6 (416) 484-4092

NOTE: 1. Most companies have sales representatives in the major study area cities such as Winnipeg, Edmonton, Calgary, and Vancouver in addition to the head offices listed above.

4.4.1 Water and Wetting Agents

Watering using fresh or sea water has been used successfully on unpaved roads for short-term dust suppression only and is usually done in confined areas such as access roads or construction sites.

4.4.1.1 Mechanism

Wetting agents are often mixed with water to extend the effect of roadway watering. These agents reduce the surface tension of water and promote penetration to the subsurface. Moisture that evaporates from the soil surface is replaced by subsurface moisture through capillary action (Midwest Research Institute 1981).

Alchem 8808 is an example of a wetting agent. Alchem 8808 is comprised of aliphatic hydrocarbons and surfactants which induces road penetration and subgrade wetting. The subgrade then acts as a moisture reservoir, replacing road surface moisture lost through evaporation.

4.4.1.2 Environmental Considerations

No adverse environmental effects have been documented in the literature from the use of water and wetting agents such as Alchem 8808. The use of salt water from the sea may have similar environmental impacts as those identified for deliquescent chemicals in the next section.

4.4.1.3 General Application Procedures

It requires approximately 6000 litres of water to spray one kilometre of minor road at a rate of one litre of water per square metre. The dilution ratio of water to wetting agent varies from 4,500 to 45,000 litres of water per litre of wetting agent, depending upon soil conditions and manufacturers' recommendations. Compacted soils require less water than do looser surfaces (Midwest Research Institute 1981).

4.4.1.4 Effectiveness/Durability

The frequency of water application depends primarily upon local weather conditions. The suppression of dust using water alone as a permanent control measure would require an application every dry day where the temperature was above 0°C. No test data have been reported that assess the relative control efficiencies of wetting agents. One manufacturer claims that wetting agents can extend the usefulness of road watering by 33 percent (Bohn 1981).

Sea water has been found to be more effective than fresh water due to contained deliquescent chemicals, primarily magnesium chloride (Road Research Laboratory 1979).

4.4.1.5 Costs

As a permanent control measure, road watering is estimated to cost from $25,000 to $40,000/km per year (Cowherd et al. 1974). Regional variations in water prices and availability, not considered here, would be expected to increase the geographical variation in these annual costs between western provinces and the northern territories. If wetting agents are used, the cost of wetting roads could be reduced to a range of $17,000 to $26,000/km per year.

4.4.2 Deliquescent and Hygroscopic Chemicals

Calcium chloride ($CaCl_2$) sodium chloride (NaCl) and salt brines from natural gas wells are the primary deliquescent and hygroscopic materials used for road dust suppression.

4.4.2.1 Mechanism

Deliquescent chemicals attract water from the atmosphere and this helps to maintain the moisture film that binds the soil particles together

(Rostler et al. 1967). Moisture from the air appears on the chemical crystals and is transferred by capillary action to the soil particles. Dust suppression is effective if sufficient treating chemical is present on the road surface and the humidity of the air is high enough to provide the water (Bell 1976).

4.4.2.2 Environmental Considerations

The environmental impact of road dust suppressant salts on the surrounding roadside environment has not been well documented in the literature. However, it is known, that salts such as calcium chloride applied for dust suppression purposes initially penetrate a road to a depth of several centimetres and then, with time, rise to the surface by capillary action (Midwest Research Institute 1981). Once on the surface the salts are susceptible to being washed off by rain.

Although salt based road dust suppressant impacts have not been well documented, impacts of salts used as de-icing agents have been well documented. The impact of salt based road dust suppressants, will be similar to de-icing agents as they are the same materials. However, the degree of impact is much reduced for dust palliatives because they are applied at much lower concentrations.

The following impacts have been noted in the literature for calcium chloride and sodium chloride de-icing compounds:

- has contaminated potable water supplies by increasing the level of chlorides (Hutchison 1969, and Schroufhagel 1967);
- is chronically and acutely toxic towards plants such as fruit trees (Midwest Research Institute 1981);
- may disrupt the osmotic balance within plant cells and interfere with normal photosynthesis and respiratory processes (Midwest Research Institute 1981);

- salt absorbed through the roots will result in premature coloration and early leaf fall the following year (Midwest Research Institute 1981);
- concentrations greater than one percent chlorides puts all freshwater species of bacteria, algae, invertebrates, fish and higher plants in jeopardy (Adams not dated);
- may induce stratification in small bodies of water and prevent mixing and thus contribute to deoxygenation of the lower depths (Dument 1972);
- may accelerate contamination of ponds and lakes by existing mercury and other heavy metals by interfering with the ability of bottom sediments to bind these toxic substances (Adams not dated); and
- may cause corrosion of vehicles using the road.

A positive aspect of calcium chloride is that it does not affect the safety of a road. In 1977 the Ministry of Transportation and Communications of Ontario conducted skid tests on test roads in Haldimand Township. An empirical value, called the SN_{30} number, was used to compare the skid potential of various surfaces. The summary of the results of the 1977 tests were as follows:

Treatment	SN_{30}
None	48 (avg. 4 roads)
Calcium Chloride	48 (avg. 3 roads)
Waste Oil	36 (avg. 4 roads)

The results indicated that oiled roads showed 25% less skid resistance than either untreated or calcium chloride roads. The values, however, are dependent upon humidity, road roughness and loose gravel (Ontario Interministerial Committee on Waste Oil Recycling 1981).

Environmental Consideration Critique

There is a dearth of information on the environmental effects of deliquescent and hygroscopic chemicals. Information which is available primarily addresses the environmental aspects of calcium chloride as a de-icing compound. This base of environmental information is inadequate to evaluate the environmental effects of calcium chloride as a dust suppressant let alone other deliquescent and hygroscopic chemicals. Studies addressing the environmental effects of deliquescent and hygroscopic chemicals are required. Specific consideration should be given to the subtle effects of low levels of suppressant contamination to "resistant" species after repeated applications over a long period of time.

4.4.2.3 General Application Procedures

Road surface conditions and traffic volume dictate the amount, timing and frequency of calcium chloride (or other deliquescent material) application. Calcium chloride, in either the liquid or flake form is usually first applied in the spring with a second application three to six weeks later. If dry flake is to be applied, a water spray prior to application is recommended (Road Research Laboratory 1971). According to one vendor, several applications are required to build up a hard-pack surface that will substantially reduce dusting for prolonged periods. For roads with traffic volumes of 200 to 300 vehicles per day, three applications within a 15-day period may be required (Walsh 1980).

Spread rates are known to vary from 0.5 to 5 L/m^2, depending on soil, climate and intended purpose. The dry flake calcium chloride is distributed onto the surface by means of an automatic spreader. Liquid calcium chloride is best applied by a truck equipped with a stainless steel tank and a spray bar controlled by a pump that meters out the solution at the desired constant spray rate (J. Keith, pers. comm.). In northern and western Canada marketers of calcium chloride will, through a subcontractor, apply the material upon request.

4.4.2.4 Effectiveness/Durability

The deliquescent effect is much greater for calcium chloride than for sodium chloride (or for other deliquescent materials) because the critical relative humidity of calcium chloride is approximately 30 percent compared with 80 percent for sodium chloride. This means that any atmospheric humidity in excess of 29 percent will be absorbed by the calcium chloride.

A recent study by the Nebraska Health Department found that a single application of 38 percent calcium chloride solution, applied at a rate of 0.9 L/m^2 to an unpaved road with a traffic volume of 200 to 300 vehicles per day, significantly reduced the total inhalable particulates (less than 10 microns in diameter - see Chapter 2) for a period of two to three weeks (Walsh 1980). The reduction of inhalable particles was approximately 40 to 50 percent after 19 days. When liquid calcium chloride was used over a three to five month period, applied at three to four week intervals, total suspended particulate (TSP) levels were reduced by 81 percent on an unpaved road that carried 200 to 300 vehicles per day. Similar applications on a road that carried 700 vehicles per day resulted in a 66 percent reduction in total suspended particulates (Walsh 1980).

No quantitative test data for the flake form were found in the literature; however, the Virginia Highway Department has reportedly controlled road dust over the past several years by applying flake calcium chloride at a rate of two to three times per summer (Rural and Urban Roads 1978).

The Manitoba Department of Highways found that calcium chloride was ineffective in sandy soil areas of the prairies and that other palliatives were required (C. Jackson pers. comm. 1982).

A study conducted by the Swedish Royal Institute of Technology compared calcium chloride and magnesium chloride as dust palliatives. Since magnesium chloride can form a solution with smaller amounts of water

than can calcium chloride, it was found that 18 percent more magnesium chloride was needed than calcium chloride in order to achieve equal amounts of solution for equal lengths of effective time. The only significant difference was that magnesium chloride was more corrosive to concrete. The author concluded that calcium chloride was more acceptable as a dust binding agent than magnesium chloride.

4.4.2.5 Costs

The cost of calcium chloride in northern and western Canada depends on how close the unpaved road section is to the source of the material. Calcium chloride is available from brine wells at Amherstburg, Ontario and Drumheller and Brooks, Alberta (also the source of the bulk flake).

The cost of treating a kilometre of road 6 metres wide is about $2000/km per application, excluding labour. Annual costs per kilometre would depend upon the number of applications necessary in a particular region. The annual cost for calcium chloride treatment has been estimated to range from $3000 to $5000/km.

One county road department, however, has calculated that the actual net cost of treating a kilometre of unpaved road to be less than $100 when reduced maintenance costs and aggregate savings are considered (Rural and Urban Roads 1978).

4.4.2.6 Related Chemicals

Other simple salt-type additives with deliquescent properties such as barium chloride, copper sulfate, barium sulfate and aluminum sulfate have been utilized as dust suppressants with varying degrees of success (Sultan 1974).

4.4.3 Organic, Non-Bituminous Binders

Almost all organic, non-bituminous binders dust suppressants are lignosulfonate compounds. Mason et al. 1981 defines lignosulfonate compounds as water soluble liquid chemical byproducts from the sulfite pulping process. The exact chemical structure or composition of lignosulfonate compounds is unknown, although they are known to contain lignin and sulphur and may contain other pulping waste products, such as resin acids (Shreve in Mason et al. 1981). In order to be used as a dust palliative, some commerical lignosulfonates are "modified" to eliminate any toxic materials in the raw sulfite liquor.

The compounds may be oxidized to remove toxic sulfone groups or active toxicants may be added in order to increase their herbicidal powers (Mason et al. 1981). There are five types of lignosulfonate compounds which may be applied to road surfaces for dust suppression. These are:

- o crude lignosulfonate (untreated spent sulfite liquor);
- o calcium;
- o sodium;
- o magnesium; and
- o ammonium.

4.4.3.1 Mechanism

The lignosulfonate solution drys and the lignin fraction serves as a glue that binds the dust particles. Fox et al. (1973) states that the sulphite liquor appears to stabilize the road surface by decreasing soil permeability.

4.4.3.2 Environmental Considerations

Environmental research addressing the possible impact of lignosulfonate compounds is scarce, what little information there is, is contradictory.

S.O. Roald, a Norwegian toxicologist, conducted two studies on the effects of lignosulfonates on rainbow trout. In a 1977 study on the effects of sublethal concentrations of lignosulfonates on rainbow trout, Roald discussed a possible connection between reduced growth rates (resulting from depressed activities of rainbow trout digestive enzymes) and lignosulfonate exposure. However, a clear relationship between lignosulfonate concentrations and growth retardation could not be established. In another 1977 study, Roald addressed the acute toxicity of lignosulfonates on rainbow trout. The results of this investigation indicated that lignosulfonate component of spent sulfite liquor may be an important contributor to effluent toxicity and consequently fish mortality. However, Roald suggested that further research on the effects of lignosulfonates on aquatic organisms be undertaken to verify the findings.

Fisheries and Oceans Canada has conducted baseline research into the toxicity of lignosulfonates on aquatic plant life. A 96 hour LC_{50} test was conducted with a lignosulfonate concentration of 1g/L. The results showed that the toxicity to aquatic plant life was generally very low (Zitko in Mason, et al. 1981). The Environmental Protection Service has investigated the toxicity of lignosulfonates in drilling muds. Bioassays conducted on fish indicated the drilling mud material to be moderately toxic (Holtz, pers. comm. 1982).

In the province of Ontario, spent pulping liquor had been used as a dust suppressant in the Trenton area. However, this practice was discontinued when the liquor was found to be contaminated with PCB's. The source of the PCB's was not able to be determined.

Suppliers of "modified" lignosulfonate compounds for dust palliation in northern and western Canada claim that their products are essentially non-toxic (McKenzie and Feimann 1982). This is supported by research in B.C. Research in British Columbia and Van Belle in Yakima County, Washington.

Studies conducted by B.C. Research into pulp mill effluents found lignosulfonates to be non-toxic toward aquatic organisms. Resin acids within spent sulfite liquor streams were indicated as the possible toxic materials (Mueller in Mason et al. 1981). Van Belle (1977) in Yakima County, Washington, found no environmental damage as a result of lignosulfonate application. The Yakima studies were carried out over a two year period.

Additional research in the United States has shown that the toxic effects of lignosulfonates are minimal. Calculations show that a two percent lignosulfonate-stabilized roadway subjected to a 2.5 cm rainstorm (while assuming unrealistically that 100 percent of the lignosulfonate goes into solution) produces a runoff stream of about one percent lignosulfonate by solid weight (Sultan 1976). This value is well below the maximum four percent concentration of lignosulfonate solids allowable for animal ingestion as permitted by the United States Food and Drug Administration (Sultan 1976). Mason et al. (1981) notes that the modified lignosulfonates supplied commercially are chemically different from the spent sulfite liquor waste effluent and therefore, any toxicity which may be found in spent sulfite liquor does not necessarily apply to lignosulfonate compounds sold for dust abatement. Ganin in Mason et al. (1981), has found the biochemical degradation of lignosulfonates to be a slow process, suggesting that whether or not these compounds are toxic, they will persist in the environment for a long time.

Environmental Consideration Critique

The contradiction of environmental effects of lignosulfonates as described in the preceding section, may be attributable to different forms being tested. On one hand spent sulfite liquor containing lignosulfonates are being tested, while on the other lignosulfonates prepared specifically for dust suppression purposes are being tested.

The spent sulfite experiments by Roald on rainbow trout and the Canadian government on aquatic plants and fish indicate that lignosulfonates are moderately toxic. Supplier data and work done in Yakima county on lignosulfonate based suppressants indicate no adverse environmental effects. Additional research is required to verify the above results. Special emphasis should be given to the effects of lignosulfonates on soils and terrestrial vegetation in the roadside environment.

4.4.3.3. General Application Procedures

Best dust palliation results have been obtained with lignosulfonate compounds when the road was initially scarified to 10 cm. In northern and western Canada, success has been experienced using a 1:1 dilution ratio with water and an application rate of 2 L/m^2 (Sontowski and Vliet 1977). Following application, the road should be formed into a modified A-crown with a uniform side slope of about 3-5 cm/m from the centerline. Proper crown construction is imperative because lignosulfonate-treated roads require rapid surface drainage. As a final step, the road surface should be top-dressed with lignosulfonate and compacted with a roller (Harmen 1957).

4.4.3.4 Effectiveness

A lignosulfonate material's effectiveness has been found to depend on the dissolved solids' concentration. A higher dissolved solids' content usually reflects an increase in lignosulfonate effectiveness. Sulfite liquors with lower concentrations of solids (<8 percent) will require

pretreatment to increase the solids' content (Interministerial Committee on Waste Oil Recycling 1981).

Sontowski and Vliet (1977) and Boyd and Van Couwenberghe (1980) conducted studies into the effectiveness of lignosulfonate compounds in British Columbia and Manitoba, respectively. The lignosulfonate compounds were observed to last approximately two to three months when applied at 2 L/m^2. In the Sontowski and Vliet (1977) study calcium, sodium and ammonium based lignosulfonates were evaluated as to their effectivness in suppressing dust. The results indicated that calcium lignosulfonate was 77 percent more effective than the sodium based lignosulfonate. Calcium lignosulfonate was also judged to be 55 percent more effective than the ammonium based lignosulfonate. The success of calcium over sodium and ammonium based lignosulfonates is thought to be attributable in part to the deliquescent properties of the calcium.

Field tests conducted in Alberta found that lignosulfonates had a tendency to cause potholes and create a slippery road surface in wet weather (Mason et al. 1981). In addition, the longevity of the control programs were found to be shorter than petroleum based programs (Mason et al. 1981).

The Road Research Laboratory (1979) has found that in-depth application and processing of lignosulfonates appears to be more satisfactory, due to the mixture remaining slightly plastic for a period of time. This allowed continued reshaping and traffic compaction reducing voids and rain penetration. The Road Research Laboratory (1979) noted that surface-applied lignosulfonates may require additional treatments, due to rain-destroyed binding action. This occurs with study results done in Yakima County, Washington. Effectiveness of the modified calcium lignosulfonate was found to be dependent on both soil and weather (precipitation) conditions. Lignosulfonates work most effectively on roads whose fines are in the range of 15-25 pecent.

4.4.3.5 Costs

Lignosulfonate treatment has been estimated to cost from $1500 to $5000/km in the study area. The cost would be lower if a local supply of lignosulfonates could be found. At present, in northern and western Canada, there is a potential supply of lignosulfonic acids available from sulfite mills. However, in the study area, the market is not strong enough to convince sulfite mill operators to incorporate the design changes necessary to redirect the stock lignosulfonate to palliative markets. Presently, the United States provides all lignosulfonates used in western Canada.

4.4.4 Petroleum Based Suppressants

Petroleum products, either in solution or emulsion form, are the most commonly used materials for road dust suppression. Several types of petroleum products are available to suit the porosity of the road surface, application equipment, evaporation or "curing" temperatures and intended results. In general, lower viscosity petroleum products are applied on roads with larger aggregate and less fines while higher viscosity products are applied on roads comprised of smaller particles. Tables 4-2 and 4-3 identify petroleum-based suppressants which may be used on unpaved roads.

4.4.4.1 Mechanism

When a petroleum-based material is sprayed on an unpaved road, surface penetration will occur to a design depth coating particles of gravel, sand and dust with a thin film. In the case of a rapidly-curing suppressant, a sticky residue which cements the aggregate into solid mat will be left behind. In the case of a medium to slow-curing petroleum-based suppressant, evaporation will be slow and the residue will remain soft so that the aggregate is not cemented but remains coated with an oil film.

Table 4-2

Commercial Petroleum Products Used as Dust Suppressants

Suppressant	Definition
Bunker "A"	the lightest bunker oil produced with least asphalt content and the most volatile components of the bunker oils. It is still a heavy oil in comparison to other petroleum products.
Bunker "B"	a slightly lighter oil than Bunker "C", meaning that its volatile components leave a little faster, but still a very heavy oil, as it is the dregs from the refining process.
Bunker "C"	the heaviest viscosity oil that refineries produce, with an asphalt content varying between 7 and 25%.
M.C.O.	any medium curing oil. This oil contains a selected grade of asphalt diluted with diesel fuel and medium curing refers to the length of time required for the base stock or solvent to evaporate and leave the hardened asphalt. (R.C. = rapid curing; S.C. = slow curing)
M.C. 2	a heavy, very viscous, medium curing bunker oil with an arbitrary weight specification of "2"; the light end of the scale being 1 and the heavy end being 6. The particular base stock used here in mixing with the asphalt is naphtha. This is the same oil used to make cold mix asphalt.
DL 10 dust oil	a brand name for a heavy residual fuel oil that is diluted with straight-run heavy crude oil (as it comes from the well).
Road oil	a bunker oil sold by the refineries, also known as spray oil, which is intended to prime a gravel road in readiness for asphalt, but which varies greatly in asphalt content.
Asphalt road primer	a heavy fuel oil whose viscosity is reduced to whatever is desired by adding petroleum distillate. Like road oil or spray oil, it is intended to prime gravel roads for receiving asphalt, and is straight-sprayed and left in the open.
Decant oil	a fluxed oil which is the heaviest oil from the cracking process, but a lighter oil compared to bunker oil, equivalent to a furnace fuel or stove oil.
Crude oil	naturally occurring, unrefined oil as it comes from the wells. Varies widely in chemical composition, especially in its hydrocarbon content. Viscosity can vary greatly, along with naturally occuring impurities such as sulphur.

Table 4-3

Used Petroleum Products Used as Dust Suppressants

Used Product	Definition
Re-refined oil	an oil that has been previously used but cleaned and refined to a level indistinguishable from virgin oil.
Waste oil	used lube oil collected from service stations; possibly distilled once over, but not necessarily.
Used transformer oil	oil used previously in transformers as a heat exchange medium.

4.4.4.2 Environmental Considerations

Petroleum Based Suppressants. The environmental aspects of petroleum-based suppressants have not been well documented in the literature. The bulk of the information which is available addresses the environmental concerns of used lubricating oil. However, the properties of used lubricating oil differ in some respects from those exhibited by commercial petroleum based suppressants.

The environmental concerns related with commercially available petroleum based suppressants arises from the properties of the oil itself. Used lubricating oils on the other hand may be contaminated with foreign material which contribute to the potential for environmental impact.

Commercial suppressants will if properly applied cause minimal environmental degradation. The properties of the commercial suppressants are such that the suppressant generally remains in the road bed. This characteristic is related to increased viscosities and densities of commercial suppressants (Bell, 1976).

The Midwest Research Institute (1981) states that emulsified asphalt based suppressants are environmentally compatible. The Research Institute has found that they are generally non corrosive, insoluble in water, non evaporative, relatively non-toxic and do not adversely affect plant life. Petroleum based resins however, which contain hydrocarbon solvents can cause air pollution when the solvents evaporate (Midwest Research Institute, 1981).

Used Lubricating Oil. Mason et al. (1981) states that applying used lubricating oil to gravel roads poses a considerable environmental threat because of the heavy metals (especially lead), polynucleated aromatics (PNA's) and polychlorinated biphenyls (PCB's) which it may contain. The oil, if applied in this state may harm the surrounding

Table 4-4

Typical Used Automotive Oil Composition and Properties

Property	Value
Gravity	24.6 API
Viscosity @ 100°F	53.3 (centistokes)
Flash Point, °F	215 °F
Water (by distillation)	4.4 (vol.%)
Sulphur	0.34 (wt.%)
Ash	1.81 (wt.%)
Lead	1.11 (wt.%)
Calcium	0.17 (wt.%)
Zinc	0.08 (wt.%)
Phosphorus	0.09 (wt.%)
Barium	568 (ppm)

Source: Ontario Interministerial Committee on Waste Oil Recycling, 1981.

vegetation and can contaminate the water supply, either by runoff or through leaching to the water table. Table 4-4 lists the typical properties and composition of used automotive oil.

Lead is the contaminant consistently found in the highest concentrations in used crankcase oil; however, as the use of unleaded gasoline increases, it is expected that the concentrations of lead will decrease (Ontario Interministerial Committee or Waste Oil Recycling 1981).

In the late 1970's, the presence of an organic contaminant of unknown origin, polychlorinated biphenyl (PCB), was noted in the waste oils of Ontario, as well as the study region. Concentrations detected were variable, ranging from less than 5 mg/L to as high as 1135 mg/L; the majority of the readings were at the low end of the range (Ontario Interministerial Committee on Waste Oil Recycling 1981). The number of contaminated waste oil samples found and the levels of PCB detected have steadily decreased, and, in Ontario, all measurements reported in 1980 were below the provincial guideline of 25 mg/L. The source of PCB in the past is suspected to have been primarily due to unsegregated collection, handling and storage of waste oil by the oil collectors (Ontario Interministerial Committee on Waste Oil 1981).

Limited field research has been undertaken to address the environmental concerns over the practice of road oiling. Freestone's (1972) report addressing the environmental effects of road oiling is one of the most quoted papers on the subject. Freestone surveyed two rural roads in New Jersey to determine whether or not oils applied for dust suppression purposes left the road. Analyses indicated that roughly one percent of the total oil estimated to have been applied remains in the top three cm of road surface material, that oil penetration below the top three cm was minimal and that lead (approximately 200 mg/kg) was concentrated in the top three cm of road material. Soil samples taken from a field subjected to runoff from an oiled road showed significantly higher lead content than soil taken from a field 40 m from the road.

Freestone (1972) also conducted laboratory weathering experiments which indicated an estimated weathering loss of oil from a road to be approximately 18 percent. Rain runoff studies on simulated road surfaces indicated two mechanisms by which oil is transported from the road:

- leaching of the oil by flotation; and
- flotation of oil-wet soil particles.

The greatest oil transport was found to be during the first few rains after oil application, with continuous, low level leaching during each subsequent rain.

Bell (1976) criticizes Freestone's report on a number of points. A summary of the primary conclusions of the critique is provided below:

- The road surface in the field was of a high density (clay material) and no surface preparation (addition of gravel course, scarification) was done to help the oil penetrate the road surface. This condition enhanced oil runoff.
- The rate of oil application was greater than that recommended by the Asphalt Institute, resulting in more oil being available for runoff.
- Lead levels found in soils and plants along the test road were considered high, but never compared with other areas. A comparison with rural Ontario roadside ditches indicates lead levels lower than at the Freestone test sites.
- The laboratory runoff test was very severe, in that a month's rainfall was applied in one day of test and four month's rain in five days of tests.

A two-year study was undertaken by L.S. Love and Associates (1979) in Ontario to compare the relative migration rates of waste oil and calcium chloride and to assess the environmental consequences of migration. The findings of the study indicated that both waste oil and calcium chloride were discharged off the road and into the adjacent environment. The loss of waste oil from the treated roadbed in the 1978 test was approximately equal to the amount of waste oil applied during 1978. The prime transfer route was identified as run-off water during rainfall. The Love Study also indicated that lead and PCB contained within the oil also left the road surface. It was implied that these materials would ultimately enter fish-bearing waters (Ontario Interministerial Committee on Waste Oil Recyling 1981).

The Ontario Ministry of Environment conducted a study from 1978-1980 into the effects of PCB uptake on yellow perch and freshwater clams in the Muskoka Lakes region (Suns et al. 1980). Fish residue analyses showed that PCB concentrations were significantly elevated in lakes that were affected by the runoff from waste oil applications. In total, 71 percent of all the fish samples analysed from lakes affected by road oiling exceeded the P.C.B. guideline for wildlife protection. The freshwater clam experiment also showed a significant uptake of PCB's.

The correlation of road oiling and P.C.B. uptake by the two aquatic species is questioned by the Ontario Interministerial Committee on Road Oiling (1981). They indicate that the uptake of metals by the test species was not abnormal and that the results of the 1980 sampling program showed a progressive decrease in the concentration levels of P.C.B. in the test species over the three year experiment period.

In 1977 the Ministry of Environment in Ontario conducted an investigation into the potential effects of road oil contaminants on soil and vegetation adjacent to oiled roads. The investigations were unable to detect any significant contamination of soil or vegetation with lead or polycyclic aromatic hydrocarbons (Ontario Interministerial Committee on Waste Oil Recycling 1981). The findings of the above study agreed with

studies conducted by Lagerwerff et. al. in 1970. Lagerwerff studied the contamination of roadside soil and vegetation with cadmium, nickel, lead and zinc. Lagerwerff was of the opinion that lead was rarely taken up directly by the roots of plants, hence, oil runoff would not be responsible for lead contamination of plants. He found that lead contamination of plants in the proximity of oiled roads was more apt to be a consequence of airborne metal than of soil-borne adsorption.

Environmental Consideration Critique

The environmental impacts of commercially available petroleum based suppressants are unknown. Environmental impact information, for the most part, has been inferred from oil pollution and used lubricating oil studies. Oil pollution research has been related to environmental emergencies or bioassay studies on organisms and cannot be directly related to the small amount of oil found within a commercial product properly applied to a road surface. Used lubricating oil studies tend to concentrate on the impurities of the used oil such as lead or PCB's.

Research is required to identify the environmental impact of petroleum based suppressants. The findings of this research would be invaluable as up to now, the impact information available for petroleum based suppressants, has placed considerable reliance on a repetition of authorities whose findings themselves have been called into question. This is underscored by the Bell (1976) critique of the Freestone (1972) report.

4.4.4.3 General Application Procedures

Petroleum based suppressants can be either sprayed or mixed into the road material. An application rate of 1.1 - 1.6 L/m^2 is considered to be the normal range of application; however, rates as high as 2.7 L/m^2 have been noted (Freestone, 1972). Specific application rates for each suppressant are given in Chapter 6 for the study area.

Generally, tankers equipped with perforated spray bars are used to spread the petroleum products as evenly as possible over the travelled area of road. In some instances, a single yearly application in late spring or early summer suffices; however, under certain conditions, such as a wet spring, it may be necessary to supplement the original application with a second or third, later in the season (Ontario Interministerial Committee on Waste Oil Recycling 1981).

4.4.4.4 Effectiveness/Durability

There are two basic mechanisms by which petroleum suppressants work:

- those that form a surface mat or crust by cementing aggregate together; and
- those that leave a film.

The effectiveness of each mechanism is dependent upon where they are applied. The surface-mat type of treatment is preferred on both rural roads having high-speed vehicles and village streets with their slower speed, higher density traffic. This type of treatment provides an excellent driving surface, free from dust, mud and loose gravel in the period until frost damage occurs. Surface-mat treatment requires extensive maintenance, especially in the two week period after application, in order to repair small surface breaks which rapidly form potholes if left unattended. A road with numerous potholes must be scarified to eliminate this traffic hazard and the dust abatement is lost. Scarification is also required each spring, since the mat is broken by frost damage (Bell 1976).

A dust-laying treatment which leaves a film is recommended where extensive maintenance cannot be provided. The treatment eliminates the dust problem and a smooth, hole-free gravel surface is maintained by occasional blading, which does not destroy the dust abatement characteristics of the treatment (Bell 1976).

Research in Prince Edward Island has shown that petroleum products, especially Bunker A Oil, will develop potholes in very wet weather (Mason et al. 1981).

4.4.4.5 Cost

The cost of treating unpaved roads to suppress dust is determined primarily by the delivered price of the petroleum product. Transporting this treating material from the point of manufacture to the rural road is a significant factor in cost, since these distances can be great. Used lubricating oil is usually the cheapest suppressant available (one half to two thirds the cost of a commercial suppressant) to a community because it can be obtained locally or closer to the roads being treated, and, accordingly, transportation costs are greatly reduced.

However, the cost of commercially-available petroleum-based suppressants has risen rapidly since 1973. Treatment costs in the study region may range from $2,500 to $6,000/km/year.

4.5 COST/BENEFITS OF ROAD DUST CONTROL

According to the Road Research Laboratory (1979), the cost of controlling road dust is dependent on climate, materials available, and economics of the region. In an area where materials are susceptible to freeze-thaw and/or high water tables, the cost will be high. Where materials are more frost stable or drainage is good, reduced thicknesses of construction are possible. From the soil materials standpoint, low plasticity, low fine content gravels are best, and more amenable, to low-cost dust-laying techniques. Within some areas, therefore, dust-laying may be more expensive and require greater maintenance than adopting higher type roadway design and construction techniques. The approximate costs of a road dust control program may be estimated from the preceding discussion of control alternatives and knowledge of the control area.

The benefits arising from a road dust control program are difficult to quantify. Values other than dollars enter into control decisions. The measures of air pollution are more reliable than the damage it causes. Documented mathematical functions that relate levels of pollution and costs are lacking. The point of diminishing returns for control expenditures cannot, at this time, be determined (Roberts 1974).

However, control decisions must be made on the basis of available information, as well as an understanding of those values in the community that cannot be quantified. Table 4-5 summarizes the potential environmental and social impacts of road dust suppressants. Table 4-6 identifies the benefits which would accrue from suppressing dust as well as not suppressing dust.

Table 4-5

Environmental and Social Impacts of Road Dust Suppressant Alternatives

Suppression Alternative	Potential Environmental Impacts	Social Impacts
NO SUPPRESSION	o Dust may affect vegetation by increasing heat absorption and reducing transpiration causing a heat build up in the leaf. o Dust affects sphagnum moss, by reducing water content, chlorophyll content and carbon uptake and increasing temerature, mineral ion concentration and pH in plant water. o pH, electrical conductivity and nutrient relationships of soil may be affected either positively or negatively depending on elements contributed by road dust. o Road dust may affect aquatic plants and fish by contributing to increased sedimentation.	o Increased accident potential due to loss of visibility skidding and swaying of vehicles, less positive steering response and broken windshields. o Reduction in the quality of life. o Lowering of property values. o Increased cleaning costs. o Retention of particles (less than 2 microns) in lungs.
TRAFFIC CONTROLS	o None Apparent.	o Travel time loss.
PAVING	o None Apparent.	o Travel time reduced. o Decreased accident potential from poor visibility. o Less vehicle maintenance.
WATER AND WETTING AGENTS		
Water (Fresh or Salt)	o Salt Water may have impacts similar to calcium or sodium chloride	o None apparent - o short-term dust suppressant life. o salt water may have impacts similar to calcium or sodium chloride

Suppressant	Environmental Considerations	Social Considerations
Alchem 8808	o Apparently incurs none of the environmental problems often associated with waste-oil use.	o None apparent - short-term dust suppressant life o Skin irritant.
DELIQUESCENT AND HYGROSCOPIC CHEMICALS		
Calcium Chloride Sodium Chloride Natural Brines	o Generally non-toxic due to rapid dissolution in the environment. o Toxic to some plants such as fruit trees if concentrated.	o May be concentrated in ground-water o Surface "crust" may be slippery in wet weather. o Possible corrosion to vehicles
ORGANIC, NON-BITUMINOUS BINDERS		
Calcium Lignosulfonate Sodium Lignosulfonate Magnesium Lignosulfonate Read Chemicals Lignosulfonate Ammonium	o Biodegradation slow - persistent in the environment. o Moderately toxic to rainbow trout and aquatic plants	o Molasses-like smell o Road surface may become slippery in wet weather.
DC-M18	o Initial tests by manufacturer indicate DC-M18 is non-toxic, non-acidic and biodegradable	o No strong odor.
PETROLEUM BASED SUPPRESSANTS		
Used Oil, Waste Oil	o Used oil may impose an environmental threat because of contaminants such as heavy metals (especially lead), P.N.A's and P.C.B.'s. o Potential of hydrocarbons and contaminants entering surface water or groundwater in high water table areas - should not be applied near these areas.	o Hydrocarbon taste problem in water if it leaches to the water table. o Use of used oil for dust suppression has been discouraged at the provincial level due to economic and environmental concerns.
Bunker Oil	o Potential hydrocarbon contamination of nearby watercourses, and groundwater.	o Use of petroleum products for dust suppression is generally discouraged at the

Suppressant	Environmental Considerations	Social Considerations
PETROLEUM BASED SUPPRESSANTS (continued)		
	o Full environmental implications of use not well researched. o Contains hydrocarbons that may be potentially toxic.	provincial level due to economic and environmental considerations. o Smell or appearance may be less desirable than other dust suppression alternatives.
DL-10	o Product generally remains in the roadbed. o Potential hydrocarbon contamination of local water bodies, particularily if applied excessively.	o Strength of odor unknown.
Emulsified Asphalt Primer	o Product generally remains in the surface course. o Potential hydrocarbon contamination of local water bodies, particularily if applied excessively.	o Strength of odor unknown.
Coherex	o Apparently non-injurious to plant growth. o Some impacts have been noted in the U.S., details unavailable at time of printing.	o Strength of odor unknown. o Yellow colour only while products cures.

Table 4-6

Benefits of Road Dust Control vs No Road Dust Control

Road Dust Control	No Control
o visibility, vehicle operating safety increased o property values increased o road maintenance costs reduced o cleaning costs reduced o vehicle maintenance costs reduced o health care costs reduced o dust related air, water, soil and vegetation impacts reduced	o possible enrichment of surrounding soils with chemical elements contained in dust o adverse environmental effects associated with suppressants avoided o capital expenditures associated with suppressant application saved

CHAPTER 5

WASTES SUITABLE FOR ROAD DUST SUPPRESSION

CHAPTER 5

WASTES SUITABLE FOR ROAD DUST SUPPRESSION

5.1 INTRODUCTION

The use of waste materials for dust palliation has not been a high priority for transportation department authorities. However, as costs of commercial materials continue to rise, alternatives must be sought.

5.2 CHARACTERISTICS REQUIRED FOR SUPPRESSION

To be suitable for dust suppression purposes, a waste must be environmentally acceptable and provide a reasonable degree of dust abatement. In addition, the candidate waste should exhibit the following performance characteristics:

- o be easily applied with existing equipment;
- o lend itself to standard maintenance methods of blading on gravel surfaces;
- o provide reasonable retention to reduce or eliminate subsequent applications;
- o provide little loss of riding quality; and
- o be cost-effective and readily available.

5.3 WASTES PRESENTLY USED AS SUPPRESSANTS

There are a number of products, previously regarded as waste, being utilized as dust suppressants. These waste products include:

- o lignosulfonates;
- o used lubricating oil;
- o salt brines; and
- o whey.

5.3.1 Lignosulfonates

As identified in the technical discussion of Chapter 4, lignosulfonate materials are one of the more popular and effective dust supressants in northern and western Canada. Lignosulfonates are a good example of a waste material (from the spent sulfite pulping process) becoming an economically viable byproduct. However, for dust suppression purposes, the potential of the spent sulfite pulping process has not been tapped in northern and western Canada. Presently, the source of lignosulfonate based suppressant materials used in British Columbia and Alberta is the Georgia Pacific sulfite mill at Bellingham, Washington. In Manitoba, the source of lignosulfonates is paper mills in Wisconsin.

5.3.2 Used Lubricating Oil

Used lubricating oil has been one of the more popular waste products utilized as a dust suppressant in northern and western Canada (Chapter 4). However, in recent years, the value of petroleum has risen appreciably, and recycling and reuse are now the preferred methods of utilization. In addition, environmental questions have arisen concerning the application of used lubricating oils on roads. The economic and environmental factors have contributed to a reduction in the amount of used lubricating oils used as a dust suppressant in the study region. Regardless, used lubricating oil has been one of the most commonly used dust suppressants on northern and western Canada roads.

5.3.3 Salt Brines

A waste product receiving acceptance as a dust suppressant in the London, Ontario area is salt brine from natural gas wells. The primary dust laying agent within the brine is calcium chloride. Depending on the gas well from which the salt brine originates, calcium chloride concentration may vary from 6 percent to 20 percent. Table 5-1 provides laboratory test results of two salt brine samples.

The brine is collected by contractors from the well operators and stored in ponds, prior to road application. The brine is applied to roads in the London area twice a year. Application is either by power spray bar

Table 5-1

Laboratory Analysis of Two Natural Gas Well Salt Brine Samples in Ontario

Sample number	1	2
Specific Gravity	1.190	1.190
% $CaCl_2$	8.4	8.6
%NaCl	10.5	10.9
% $MgCl_2$	2.0	2.1

Source: Greenly, 1982.

or gravity spray bar. The municipalities favor the power spray bar method, whereby the brine solution is pumped under pressure from the tank truck. The province utilizes the gravity feed method.

The District Municipal Engineer has come to the following conclusions, with respect to brine application and usage:

- o if the brine solution contains 8 percent or more of calcium chloride, then it is cheaper to apply than 35 percent liquid calcium chloride from a supplier (Table 5-2);
- o the salt brine is not recommended, from a service point of view, on heavily travelled gravel roads, but does the job on low-volume gravel roads, where the maintenance service demand is not too high;
- o prolonged rain dilutes the solution in the storage ponds, and conversely, after hot weather, evaporation increases the strength of the solution; and
- o corrosion of vehicles may be experienced.

The success of salt brine usage in Ontario suggests that salt brines in northern and western Canada be studied for their applicability as a dust suppressant.

5.3.4 Whey

Waste whey from dairies in Vernon, British Columbia and Dauphin, Manitoba has been tried as a dust suppressant. In the Dauphin, Manitoba area application of the whey resulted in:

- o slippage by vehicles immediately after application; and
- o odour problems.

Further details regarding environmental impact, application rate, effectiveness or cost are not available.

Due to lack of supply, waste whey is not expected to become a viable suppressant in northern and western Canada. If significant quantities of whey were available, it would be utilized to make marketable dairy products.

Table 5-2

Cost Comparison Between "Salt Brine" Containing $CaCl_2$ and 35% $CaCl_2$ Solution

% $CaCl_2$ Solution	Tanker Size (Litres)	Unit Cost ($)	Load Cost ($)	Cost to obtain 35% $CaCl_2$ for tankerload ($)	Road Superintendent Cost/hr. ($)	Road Superintendent Cost for Number of Equivalent Loads Required ($)	Total equivalent cost for 35% $CaCl_2$ Solution ($)	Cost per litre ($)	Factor used to obtain equivalent percent.
35	21,500.	$153/Tonne*	2154.60	2154.60	10.65	10.65	2165.25	.10	1
6	21,500.	.014/Litre	301.00	1755.00	"	62.13	1817.13	.08	35/6
6	12,700.	.014/Litre	178.36	1040.63	"	62.13	1102.56	.08	35/6
8	21,500.	.014/Litre	301.00	1316.87	"	46.59	1363.46	.06	35/8
8	12,700.	.014/Litre	178.36	780.33	"	46.59	826.92	.06	35/8
10	21,500	.014/Litre	301.00	1053.50	"	37.28	1090.78	.05	35/10
10	12,700	.014/Litre	178.36	624.26	"	37.28	661.54	.05	35/10
12	21,500.	.014/Litre	301.00	877.92	"	31.06	908.98	.04	35/12
12	12,700.	.014/Litre	178.36	520.21	"	31.06	551.27	.04	35/12

* Cost per tonne of flake calcium chloride from supplier is estimated at $153.00/Tonne.

Source: B.B. Greenly, 1981.

5.4 WASTE EVALUATION

To determine whether a waste is suitable for use as a dust suppressant in northern and western Canada, extensive testing must be undertaken. The evaluation process of a potential candidate waste suitability has three distinct phases:

Phase 1: Selection of Waste to be Tested. This phase is meant to identify which types of waste materials may be suitable for suppression purposes and worthy of further research. Phase 1 is discussed in detail in this section.

Phase 2: Lab Evaluation of Waste Material. In this phase, a detailed evaluation of physical and chemical characteristics of a waste material is performed. Shortcomings of the waste material are identified, based on the laboratory analysis. The effort required to upgrade physical and chemical characteristics (by additives, for example) is delineated. Preliminary testing of material effectiveness is undertaken, prior to application in the field. At this time, an environmental evaluation of the waste materials is also undertaken.

The analytical procedures used in this phase are very waste specific and must be decided upon by the researchers involved in the evaluation. The waste specific nature of the laboratory evaluation procedures precludes further discussion within this report.

Phase 3: Field Testing of Waste Material. In this phase, road test sections are constructed and field testing conducted.

5.4.1 Selection of Waste to be Tested

To determine which types of wastes may be suitable for suppression purposes and worthy of further research, a number of "indicators" must be identified. The purpose of this discussion is to identify these indicators, through an analysis of dust suppressants presently in use. Potential "indicators" include:

- mechanisms by which existing suppressants work; and
- physical/chemical characteristics of suppressants presently utilized.

5.4.1.1 Mechanisms of Existing Suppressants

As identified in Chapter 4, there are four basic suppressant categories:

- Water and wetting agents work by reducing the surface tension of water and promoting penetration to the subsurface. Moisture that evaporates from the soil surface is replaced by subsurface moisture through capillary action. The moisture bonds the road particles.
- Deliquescent and hygroscopic chemicals work by attracting moisture from the atmosphere. The moisture is then transferred by capillary action to the dust. This moisture bonds the road particles, as in water and wetting agents.
- Organic Non-Bituminous Binders generally serve as a glue that binds dust particles.
- Petroleum based suppressants may work in two ways. The first method is by cementing the particles together, while the second method is through coating the dust particles with a thin film.

From an examination of the above mechanisms, it is apparent, that for a waste product to be a successful suppressant, it must be able to:

- attain and maintain moisture bonds between particles;
- glue or cement particles together; or
- cover particles with a film and protect them from the abrading and crushing effects of traffic.

5.4.1.2 Physical/Chemical Characteristics of Dust Suppressants

A review of the physical and chemical properties of the existing suppressants may provide us an indication of the properties which should be exhibited by potential waste product dust suppressants. Within this section, the properties of deliquescent and hygroscopic chemicals, lignosulfonates and petroleum products reported in the literature are given (Tables 5-3 to 5-5).

Table 5-3

Representative Ranges of Deliquescent and Hygroscopic Chemicals' Physical and Chemical Properties

Chemical	Specific Gravity[1]	Total Solids	ph	Deliquescence[2]	Hygroscopicity[3]
Calcium Chloride	1.261 - 1.351 (15.5°C; 15°C)	19.2 - 42%[4]	7-7.5	20% R.H. @ 38°C to 43% R.H. @ 0°C	3.73 kg @ 95% R.H. to 0.36 kg @ 30% R.H.
Sodium Chloride	-	-	-	70 to 80% R.H.	

1. The ratio of the density of a substance to the density of a substance (in this case water) taken as a standard when both densitites are obtained by weighing in air.

2. Minimum relative humidity (R.H.) at which the solid chemical will dissolve in atmospheric moisture, making it functional as a dust suppressant.

3. Amount of water absorbed by 0.45 kg of the solid chemical, at 25°C, at specific relative humidities.

4. Some natural brine sources with calcium chloride concentrations as low as 8% have been used successfully in Ontario.

Table 5-4

Representative Ranges of Lignosulfonate Compounds' Physical and Chemical Properties

Substance	Specific Gravity[1]	Viscosity[2] (centipoises)	Total Solids[3]	pH	Solids Content by Weight			Ash Content by Weight		
					Lignosul-fonate	Carbohydrates	Ash	Calcium (Ca)	Sodium (Na)	Total Ca & Na
Lignosulfonate (concentrate)	1.235-1.286 (32°C; --)	1107-330 (15.6°C; 18°C)	50.4-55.7%	4.1-6.5	70.0-83.3%	7.3-19.4%	1.0-12.9%	0.9-40.9%	2.4-38.4%	39.3-44.4%

1. The ratio of the density of a substance to the density of a substance (in this case water) taken as a standard when both densities are obtained by weighing in air.

2. The property of a fluid or semi-fluid that enables it to develop and maintain an amount of sheering stress dependent upon the velocity of flow and then to offer continued resistance to flow.

3. The effectiveness of lignosulfonate compounds depends upon the total solids within the solution. A study in Ontario has noted that the higher the total solids, the more effective the lignosulfonate dust palliative.

Table 5-5

Representative Ranges of Lubricating Oils Physical and Chemical Properties

Product	Specific Gravity[1] (60/15°C)	Viscosity[2] (sus, 34°C)	Flash Point[3]	Percentage Residue (non volatile)
Lubricating Oils (Used, Rerefined, Virgin)	0.88-0.91	310-425	>101°C	55-63%

1. The ratio of the density of a substance to the density of a substance (in this case water) taken as a standard when both densities are obtained by weighing in air.

2. The property of a fluid or semi-fluid that enables it to develop and maintain an amount of sheering stress dependent upon the velocity of flow and then to offer continued resistene to flow.

3. The temperature at which a substance will ignite and burn.

5.5 WASTES POTENTIALLY SUITABLE FOR DUST SUPPRESSION

A list of waste materials, which should be evaluated as to their suitability as dust suppressants, is presented in this section.

5.5.1 Fly Ash

Fly ash is incombustible mineral matter generated by the burning of coals in thermal power plants. Fly ash has binding and sealing properties and, if mixed with aggregate material, may be used as a dust suppressant. Fly ash is readily available in parts of Manitoba and Alberta.

5.5.2 Hydrogenated Tallow

Hydrogenated tallow is a primary amine product generated in rendering plants. Tallow has been used to suppress dust on the product in the potash industry in Saskatchewan (Robertson, pers. comm. 1982) and is also listed as a prime component of a suppressant called Aliquat 226, marketed by General Mills Chemicals in the United States (Sultan 1976). There are a number of rendering plants in each province of the study area, so tallow is readily available.

5.5.3 Sulphur

Until recently, sulphur has been considered a waste generated by the petroleum industry. However, the United States' military have investigated the possibility of utilizing modified sulphur as a dust suppressant (Baker et al. 1967). Their study indicated specialized equipment was required for application, and adverse environmental impact resulted in the form of odour problems and vegetation toxicity. The military study also suggested these problems could be overcome with further research. A drawback of using modified sulphur may be its cost. However, the amounts of sulphur available in northern and western Canada warrant further research on sulphur as a base for a suppressant.

5.5.4 Rubber Latex

A waste rubber latex is generated during the manufacture of synthetic rubber. The waste rubber could potentially be put into a solvent solution, dissolved and applied on roads for dust suppression purposes. The primary source of the rubber waste would be southern Ontario synthetic rubber plants.

5.5.5 Calcium or Magnesium Carbonate

Calcium or Magnesium Carbonate precipitated as a result of water softening operations could potentially be a dust suppressant. However, there are collection problems and cost factors which would have to be addressed.

5.5.6 Magnesium Chloride

Magnesium Chloride is a byproduct of the Kaiser Chemical operations on the Great Salt Lake Flats. Magnesium chloride has potential for dust control on sand based roads. Specific details are unavailable at present, however, similarities to salt bearing areas in Saskatchewan do exist. A review of the Kaiser operations and their applicability to Saskatchewan is warranted.

CHAPTER 6

ROAD DUST SUPPRESSION IN NORTHERN AND WESTERN CANADA

CHAPTER 6

ROAD DUST SUPPRESSION IN NORTHERN AND WESTERN CANADA

6.1 INTRODUCTION

In British Columbia, Alberta, Manitoba and Northwest Territories, approximately 80 percent of roadways are unpaved and are potential dust generators (Table 6-1). An estimated combined total of six to eight million dollars is spent annually in the study region jurisdictions on dust suppression. The expenditure required for road dust suppression is justified on environmental and social grounds (see Chapter 3).

6.2 RESPONSIBILITY FOR ROAD DUST SUPPRESSION

The primary responsibility for road dust suppression in the study region lies with the transportation and highways' departments of the respective provinces and territories. The administration of dust suppression programs is similar throughout the study region and consists of two divisions within the provincial or territorial authority:

- o administrative; and
- o regional/district.

The administrative authority is responsible for the entire provincial or territorial road dust suppression program. Specific concerns are financial, political and research. Feedback is received from the district authorities on technical, environmental and economic road dust suppression matters. This information is utilized in developing departmental policy for future years. The administrative authority will also act as a consultant to counties and municipalities on their suppression programs. The administrative authorities are located in Victoria, British Columbia; Edmonton, Alberta; Winnipeg, Manitoba; and Yellowknife, Northwest Territories.

Table 6-1

Provincial, Territorial and Municipal Road Statistics*

JURISDICTION	PAVED (km)	GRAVEL (km)	EARTH (km)	OTHER SURFACE (km)	% OF ROADS UNPAVED	% OF GRAVEL ROADS HAVING SURFACE TREATMENT
Manitoba	10,717	46,264	21,270	61	86.3	3.0
Alberta	16,014	112,032	29,518	65	89.8	4.6
British Columbia	23,651	28,880	10,870	17	62.7	8.3
Northwest Territories	68	3,936	-	-	98.2	96.9

Source: Bell, 1976 and Statistics Canada, 1973

* The variation in the fraction of total road kilometres which is unpaved represents the differences in provincial and territorial traffic densities, safety requirements and highways' budgets.

The regional/district authority is responsible for obtaining suppressants and either applying or supervising their application. There are 12 districts in Manitoba, 6 regions with 15 subdistricts in Alberta and 6 regions with 37 districts in British Columbia. Technical and environmental tests on suppressants are conducted at the regional/district authority level.

Municipalities and counties are political divisions within a province or territory which may administer a road dust suppression program. Funds for dust suppression purposes are provided, by either the province or the municipality, to municipal or town engineers. The length of road administered by the municipalities or counties in the study region is small compared to the provincially administered roads. However, it is no less important because the dust generated on these roads usually affects a significant population size.

6.3 GOVERNMENT REGULATIONS

In the study area, regulations addressing road dust generation may be developed at three principal governmental levels:

- o federal;
- o provincial or territorial; and
- o municipal.

To date, development of road dust control regulations has been rare, since road dust is often tolerated (when compared to industrial emissions) and control procedures are not well developed.

At the federal level, regulations which have only a peripheral impact on road dust generation are in place. The most prominent of the Federal regulations is the Clean Air Act. The Clean Air Act sets ambient air quality objectives which apply to all particulates, whether "man-made" or "natural." The enforcement of this Act, with respect to road dust, would be difficult since no specific generation parameters are provided for in the Act.

At the provincial and municipal level in northern and western Canada, there is a dearth of regulations governing road dust generation. Provincial occupational health guidelines do address road dust generation, however, their application is limited to site specific industrial

project roads, such as those found at mining or forestry operations. The application of the occupational health regulations to all unpaved roads in the study region would not be feasible.

The only type of government guideline in northern and western Canada which specifically addresses road dust generation and control is provincial transportation department maintenance standards. Manitoba has a "300 metre policy," whereby the provincial transportation department suppresses dust along a 300 metre strip in front of a residence (Jackson, pers. comm. 1982).

British Columbia has possibly the most developed maintenance standards within the study area. Crew sizes, equipment, production goals, level of service, scheduling and application rates are all specified. An example of the British Columbia Maintenance Standard is provided in Appendix 1.

Appendix 1 also contains the Ontario specification for the supply and application of calcium chloride. This form is the most detailed available in Canada, and is provided as an example of the type of specifications developed outside of the study area.

6.4 DUST SUPPRESSANT USE IN NORTHERN AND WESTERN CANADA

6.4.1 Types of Suppressants

The most dominant surface applied dust palliatives, in northern and western Canada, in a generalized decreasing order of usage, appear to be calcium chloride, calcium lignosulfonate and various petroleum based materials. In fact, a survey by Mason et al. (1981) found that these palliatives were used extensively throughout Canada (Table 6-2).

The primary difference between jurisdictions in northern and western Canada is the philosophy behind palliation programs. Table 6-1 identifies the fraction of roads which are unpaved within a province or territory. This probably represents the differences in traffic densities, safety requirements and highways' budgets. Table 6-1 also identifies the percentage of gravel roads receiving treatment within a province or territory. The difference between level of treatment between provinces is difficult to explain, but Bell (1976) hypothesizes that concern for dust palliation is not uniform. Other reasons given

Table 6-2. Summary of Dust Suppression Practices in Canada (Mason et al. 1981).

PROVINCE/ TERRITORY	USED LUBRICATING OIL	LIGNOSULFONATES	CALCIUM CHLORIDE	OTHER
STUDY AREA				
Alberta	o not widely used at present only 2 municipalities & 1 reg. dist. use approximately 40,000 litres/yr.; o in the past approx. 800,000 litres/yr had been used on primary & secondary roads which are lightly travelled.	o field tests done found that lignosulfonates had a tendency to cause potholes & create slippery road surface in wet weather; o Dept. of Highways feels that it is not as permanent as other alternatives.	o some is being used usually where there is an aesthetic objection to oiling roads; o some public complaints with corrosion.	o a wide variety of products are used; regular cutback oil, emulsified asphalt, Bunker B or C oil, heavy crude oil; o 95% of the surfaces are prepared with an asphalt & crushed gravel combination to control dust, o municipalities also use above construction technique for their dust control; o counties & municipalities also use proprietary enzyme products (e.g.'terrazyme'), however, these are not as effective as other available stabilizers.

(continued)

Table 6-2 (continued)

British Columbia	o in 1979-80 approximately 2.4 million litres of used lubricating oil applied; o decrease in use advocated, due to environmental and recycling considerations.	o in 1979-80 approximately 4.4 million litres of modified calcium lignosullfonate applied with success; o sodium and ammonium base used in the past, but found not to be as effective as calcium base.	o most popular suppressant in B.C., with 4.6 million litres applied in 1979-80; o surface crust is created, with calcium chloride o may be slippery in wet weather	o asphalt is the only other dust palliative utilized in British Columbia in any quantity, with 400,000 litres applied in 1979-80 - this amount is a marked decrease from the 3 million litres applied in 1977-78.
Manitoba	o used in only 2 of 12 highway districts; o municipalities and small towns still use oil, but use is generally discouraged.	o test strips have been conducted, with successful results; o no widespread use of lignosulfonates at the present time.	o basic dust suppressant for whole province; o used with success, except on sandy soils.	o waste whey products from dairy used near Dauphin, Manitoba.
Northwest Territories	o utilized for suppression purposes by small communities and private service station operators.		o used with success in Territories.	
OTHER JURISDICTIONS				
Saskatchewan	o applied to gravel roads in small communities.	o poor success	o used on highways, best results are found north of Prince Albert; o best & cheapest product available.	o asphalt products are sometimes used on highways.

(continued)

Table 6-2 (continued)

New Brunswick	o none used by the Provincial Department of Transportaton		o liquid or flake $CaCl_2$ is only used by the Dept. of Transportation	
Newfoundland & Labrador	o none used by the Department of Transportation		o liquid or flake $CaCl_2$ is only used by the Dept. of Transportation	
Ontario	o used only by municipalities. o quantities available may be limited in future	o available locally for use by municipalities	o main compound used; o primarily, the liquid $CaCl_2$ is applied to highways.	o asphalt prime also used for highways; o salt brines used in London, Ontario area.
Nova Scotia	o in 1978,450,000 litres were used for dust concontrol only on private property or municipal road systems		o usually the liquid form is used; in 1980, approx. 760 km were treated.	o asphalt prime is also used, but use restricted to heavily travelled roads because the cost is more expensive than $CaCl_2$.
Prince Edward Island			o approx. 275 tonnes per year used; o poor quality soils take longer to recover in the spring if $CaCl_2$ is applied; o may require 2-3 treatments per season for adequate control.	o Bunker A oil is applied on lower road sections; use approx. 68,000 litres/yr; o pothole development occurs in very wet weather; o roads with a high clay content may have to be done twice.

are budget limitations, availability of treating materials and concern for water pollution by treating materials (Bell 1976). Decisions, with respect to which roads are to receive treatment in a given year, may be based on the following:

- o annual petition by property owners; and
- o safety aspects and traffic counts.

6.5 APPLICATION RATES OF SUPPRESSANTS

Application rates of dust suppressants utilized in northern and western Canada appear more a matter of judgement (often at rates suggested by the supplier), even though criteria for application of such products may be specified by Provincial transportation officials. The British Columbia Ministry of Highways (1978) maintenance standard, for example, states that dust palliatives should be applied at the following rates, allowing for differing surface conditions:

Calcium Chloride (liquid)

liquid @ 35% concentrate.....1.35-1.65 litres/m^2

equivalent flake.....0.81-1.10 kilograms/m^2

Bunker Oil.....1.10-1.35 litres/m^2

Lignosulfonate (1:1 water dilution).....1.90-2.20 litres/m^2

Second applications are to be 1/2 to 2/3 of original rate of application.

Application rate ranges for the most common dust suppressants used throughout northern and western Canada are provided in Table 6-3.

6.6 FREQUENCY OF SUPPRESSANT APPLICATION

Frequency of application of a palliative ranges from an annual oiling, to specific programs of twice a season for calcium chloride or calcium lignosulfonate, to a strictly on-demand basis.

Table 6-3

Application Data For Most Common Dust Suppressants Available in Northern and Western Canada*

Suppressant	Application Range	Application Strength	Number of Applications
Water and Wetting Agents			
Alchem 8808	Add 2-3% concentration to water which would usually be applied. (0.5% Once base built-up)	-	Every 2-3 days
Deliquescent and Hygroscopic Chemicals			
Calcium Chloride	0.5-5.0 L/m^2	generally 35%	minimum of one application per season
Sodium Chloride	0.5-5.0 L/m^2	-	usually more than calcium chloride in same area.
Salt Brines	>7% Calcium Chloride	Full Strength	2 or more applications per season.
Organic Non Bituminous Binders			
Calcium Lignosulfonate	1.9-2.2 L/m^2	1:1 water	minimum of one application per season
Sodium Lignosulfonate	1.9-2.2 L/m^2	1:1 water	minimum of one application per season
Ammonium and Sodium Lignosulfonate	1.9-2.2 L/m^3	1:1 water	minimum of one application per season
Read Chemicals Lignosulfonate	1-2% solid mixed into windrow	-	-
Spent Sulfite Liquor	1.9-2.2 L/m^2	Full strength to 1:1 water	-
DC-M18	1 L/22-55 m^2	1 part in 85-100 parts water	2-3 applications/year

Table 6-3
(Continued)
Application Data For Most Common Dust Suppressants Available in Northern and Western Canada

Suppressant	Application Range	Application Strength	Number of Applications
Petroleum Derived Binders			
Used Oil, Waste Oil	1.1-1.7 L/m^2	-	2 applications first year, 1-2 thereafter.
Bunker Oil	1.1-1.3 L/m^2	-	-
DL-10	1.8 L/m^2	-	3 in first season, 2 in each season thereafter.
Emulsified Asphalt Primer	1.8 L/m^2	-	1 application per year.
Coherex	2.0-3.0 L/m^2	1:4 water	-
Slow Curing Liquid Asphalt, SC30	1.3-1.6 L/m^2	-	minimum of one application first year
Liquid Asphalt, MC30	1.1-1.4 L/m^2	-	1 application per year
Emulsified Asphalt SS1	1.4-1.4 L/m^2	-	1 application per year
Asphalt Road Primer	1.1-1.4 L/m^2	-	-
Decant Oil	1.1-1.6 L/m^2	-	-
Re-refined Oil	1.1-1.6 L/m^2	-	-
Heavy Crude Oil	1.1-1.6 L/m^2	-	-

* Application ranges, application strength and number of applications as reported by transportation officials or suppliers for the study region.

6.7 PERFORMANCE OF DUST SUPPRESSANTS IN NORTHERN AND WESTERN CANADA

The effectiveness of dust suppressants utilized in northern and western Canada has not been well documented. The bulk of the evaluation results of suppressant performance is contained within transportation files. Only three studies have been prepared in a manner suitable for general review. The three studies include Mulholland 1972; Sontowski and Vliet 1977; and Boyd and Van Cauwenberge, 1980. These studies are primarily concerned with deliquescent chemicals and lignosulfonate materials.

Mulholland (1972) evaluated the performance of several common materials as dust palliatives on secondary highways in the Prince Albert area of Saskatchewan. The palliatives reviewed were calcium chloride, sodium chloride, combination of the two chlorides, emulsified asphalt and calcium lignosulfonate. Each palliative was evaluated with respect to ease of application and maintenance, durability and life, cost and performance.

Mulholland (1972) test section results indicated that all palliatives tested provide some degree of dust control. Sodium chloride, however, regardless of application rate, did not yield satisfactory dust control in dry weather.

The calcium chloride and sodium chloride mixture yielded good dust control, but it was not proven that the extra effort required to add and dissolve the sodium chloride significantly increased dust abatement over that provided by calcium chloride alone (Mulholland 1972).

The asphalt emulsion section exhibited rapid formation of pitting, which was detrimental to surface riding quality. Blading was undertaken to correct this deficiency, but was unsuccessful, as reworked material did not bind in the depressions and left coarse gravel to abrade the surface. The addition of more emulsion would make the product uneconomical when compared to other products on a one-season basis, although retention is good from the first to the second season (Mulholland 1972).

Calcium lignosulfonate provided satisfactory dust control, but required a tight and stable subgrade to support the weak cementing action provided. The treated surface abraded easily under traffic and, once ravelling began, general deterioration was rapid. Heavier application rates provided longer lasting dust control, and a rate of 2 L/m^2 appeared to be the optimum rate providing reasonable dust control. The treated subgrade was found to be reworkable under proper moisture conditions. Reduced maintenance was gained over the season because the surface remained fairly stable through wet weather and less frequent blading was required to maintain surface smoothness and cross section. Because of good waterproofing characteristics, the surface was not slippery in wet or muddy weather, but lengthy rainfall may leach this palliative from the surface (Mulholland 1972).

Mulholland (1972) found that calcium chloride provided the most satisfactory combination of dust control, ease of application, durability and cost. Although some residual treatment did carry over into the second year, calcium chloride could not be relied upon to provide sufficient retention for satisfactory dust control in a second year. The effectiveness of calcium chloride was found to be reduced by rainfall and runoff and by blading and reworking of the road.

Sontowski and Vliet (1977) evaluated calcium, sodium and ammonium lignosulfonate in the 100 Mile House highways' district of British Columbia. The lignosulfonates were applied at a coverage of 2 L/m^2. The effectiveness of the dust palliatives was evaluated by the amount of dustfall generated in the test sections during a number of sampling periods.

Sontowski and Vliet (1977) applied the lignosulfonate materials with a 1:1 water dilution ratio. The 1:1 solution was found to:

- be an economical method of application;
- cause less application difficulties than the concentrated materials;

- o facilitate greater penetration of the road surface by the lignosulfonate materials; and
- o provide adequate coverage of the road surface and effective dust control.

Sontowski and Vliet (1977) concluded that all three lignosulfonate dust palliatives were capable of controlling dustfall for some time after application to unsurfaced roads. The effectiveness of the lignosulfonate dust palliatives was observed to last approximately 2 to 2.5 months, before reapplication of the materials became necessary. Of the three lignosulfonate based materials, Sontowski and Vliet discovered that calcium lignosulfonate was 77 percent more effective than the sodium based, and 55 percent more effective than the ammonium based.

Boyd and Van Cauwenberghe (1980) conducted an evaluation, near Winnipeg, of calcium lignosulfonate as a dust palliative. The purpose of this study was to determine if calcium lignosulfonate could control dust as effectively as calcium chloride, on a similar cost basis. They found that one part calcium lignosulfonate to one part water, applied at 2 L/m^2, was as effective as calcium chloride. During the initial stages of the study (June 1980) when the weather was considerably drier and slightly warmer than normal, calcium lignosulfonate was determined to be more effective in controlling dust than calcium chloride. The final results of the study indicated that both products controlled dust equally, however, a reduction in dust control was experienced when the road surface deterioriated as a result of rain and traffic. Maintenance requirements were judged to be equal and application costs for calcium lignosulfonate were only 15 percent higher in the Manitoba area.

Historically, used crankcase oil has been one of the most popular and effective palliatives in the study region. The prime attraction of used oil was its availability, low cost and ease of application. No documented evidence quantifying the effectiveness of used oil on northern and western Canada roads was found during this study. However, due to environmental and energy considerations, as identified in Chapter 4, the use of waste oil is being discouraged by study area governments.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

7.1 INTRODUCTION

While preparing this report, research areas were identified where knowledge of specific subjects was deficient or where statistical data would be helpful. This chapter capsulizes the existing situation and makes recommendations for further study.

7.2 ENVIRONMENTAL IMPACT OF DUST SUPPRESSANTS

Report Conclusion - Until recently, dust suppressants have been chosen on technical and economic grounds, with no consideration given to potential environmental impact. This selection process is reflected in the dearth of information in the literature on the environmental impact, adverse or otherwise, of any of the various materials presently considered suitable as dust suppressants for reasons of safety, cost or aesthetics. The literature that is available, in many instances, involves considerable reliance on a repetition of previous authorities, whose findings themselves have been called into question.

Recommendation - The environmental impact of all suppressants used on northern and western Canada roads should be identified. Specific consideration should be given to long-term exposure of natural systems to low concentration levels of dust suppressant. The provinces and territories should minimize the possibility of environmental degradation by establishing a code of practice for the application of dust suppressants.

7.3 IDENTIFICATION OF DUST SUPPRESSANT ALTERNATIVES FOR NORTHERN AND WESTERN CANADA

Report Conclusion - There are a number of dust suppressant alternatives available for use in northern and western Canada. The suppressant alternatives may be of a commercial nature or, in the case of waste materials potentially available from generators. In addition, there are suppressants which have been used in other jurisdictions, but not in the study area.

Recommendation - A study should be undertaken to identify the environmental and economic suitability of all road dust suppressant alternatives. Special emphasis should be given to waste materials such as those mentioned in Chapter 5. The recycling and reuse of waste materials for dust suppression is preferred over virgin materials, if they are equal on environmental and economic grounds.

7.4 IDENTIFICATION OF THE EFFECTS OF ROAD DUST ON NATURAL SYSTEMS

Report Conclusion - Road dust is considered a pollutant which, if air quality standards are breached, may affect natural systems. The major contributor to road dust generation is slippage entrainment. No study has been undertaken in the study area to identify potential impacts of road dust on natural systems near dusty roads.

Recommendation - A study which quantifies the possible impacts of road dust on natural systems should be undertaken. A relationship between air quality standards and dust impacts should, if possible, be developed.

7.5 STUDY OF BENEFITS AND COSTS OF ROAD DUST CONTROL

Report Conclusion - Traffic controls and paving are the most environmentally acceptable and effective methods of dust control, however, economics preclude paving as a viable alternative for road dust suppression on minor roads. Where perceived to be required, chemical and petroleum dust suppressants are utilized on unpaved secondary roads. Documented functions that relate levels of dust pollution to control expenditures are not available and should be investigated.

CHAPTER 8

LITERATURE CITED AND CONTACTS MADE

Recommendation - A study should be undertaken to determine the relationship between dust pollution and control expenditures. This relationship would enable authorities to priorize control programs and eliminate cost ineffective protection procedures.

7.6 RESIDUAL EFFECTS OF SUPPRESSANTS

Report Conclusion - At present, the common practice in northern and western Canada is to apply, year after year, the same concentration of dust palliative to a road section. Calcium chloride has been known to exhibit residual effects, however, a quantification of the effectiveness has not been undertaken. A study to identify the residual effectiveness of all suppressants utilized in the study area is required.

Recommendation - Quantification of residual effects of dust suppressants from one year to the next may allow a decrease in suppressant application in subsequent years. This would result in a cost saving to the dust control agency. A field oriented study should be undertaken to quantify residual effectiveness of suppressants in northern and western Canada.

7.7 SUPPRESSANT SUITABILITY ON SANDY SUBGRADES

Report Conclusion There are a number of suppressants available in northern and western Canada which perform well on clay subgrades but, are virtually non-effective on sandy subgrades. Available strategies on sandy subgrades, which include clay capping and paving, are frequently cost prohibitive on low traffic volume roads.

Recommendation A study should be undertaken to identify road dust suppressants which are suitable for use on sandy subgrades. Consideration should be given to magnesium chloride which has been identified as a potential candidate suppressant for use on sandy subgrades (Chapter 5).

CHAPTER 8

LITERATURE CITED AND CONTACTS MADE

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8.3 DUST SUPPRESSION PROJECT STEERING COMMITTEE

Mr. James Armstrong
Waste Management Engineer
Hazardous Waste Management Division
Waste Management Branch
351 St. Joseph Boulevard
Hull, Quebec
K1A 1C8

(819)997-4334

Mr. Don Mason
Resource Recovery Section
Waste Management Branch
810 Blanshard Street
Victoria, British Columbia
V8V 1X5

(604)387-1161

Dr. A.D. McIntyre
Environmental Protection Service
Pacific Region
Environment Canada
3rd Floor, Kapilano 100 - Park Royal
West Vancouver, B.C.
V7T 1A2

Mr. Tom Rogers
Section Head, Resource Recovery
Waste Management Branch
Pollution Control Division
Alberta Environment
9820 - 106 Street
Edmonton, Alberta

(403)427-5868

Al Holtz
Environmental Protection Service
804, 9942-108 Street
Edmonton, Alberta
T5K 2J5

Mr. Bernie Scott
Environmental Protection Services
Government of Northwest
Territories
Yellowknife, N.W.T.

Mr. Dave Thompson
Section Head, Waste Management
Branch
Department of Northern
Affairs and Environmental
Management
Winnipeg, Manitoba

(204)895-5313

Mr. John Slupsky
Coordinator, Waste Management
Environmental Protection
Service
804, 9942 - 108 Street
Edmonton, Alberta
T5K 2J5

(403)420-2591

Mr. Michael Whalen
Chief, Science Procurement
2nd Floor, Oliver Building
10225 - 100 Avenue
Edmonton, Alberta
T5J 1J9

Mr. Griff Sherbin
Head Wate- Pollution and
Contaminants Control
Environmental Protection Service
804, 9942-108 Street
Edmonton, Alberta
T5K 2J5

8.4 DUST SUPPRESSANT SUPPLIER CONTACTS

Mr. H.C. Low
Product Specialist
Alchem Inc.
P.O. Box 5002
Burlington, Ontario
L7R 3Y9

(416)632-8791

Mr. Les Sherwood
Sales Representative
Alchem Inc.
260n - 82500 MacLeod Trail South
Calgary, Alberta
T2H 2M1

(403)253-8268

Mr. Jim Baxter
Regional Manager
Allied Chemical Limited
Winnipeg, Manitoba

(204)633-9279

Mr. Jim Keith
Sales Representative
Allied Chemical Canada Ltd.
Suite 823, 703 - 6th Ave S.W.
Calgary, Alberta
T2P 0J9

(403)269-2887

Mr. Olaf Klindtworth
Sales Representative
Canadian Industries Limited
800 Terminal Avenue
Vancouver 4, B.C.
V6A 2M8

(604)685-1411

Mr. Bruce McKinley
Sales Representative
Canadian Industries Limited
4605 - 101 Ave.
Box 826
Edmonton, Alberta
T5J 2L4

(403)465-0221

Denca Construction Specialities Inc.
10215 - 178 Street
Edmonton, Alberta
T5S 1M3

(403)483-7275

Mr. John Baron
Dow Chemical of Canada Limited
Suite 2600, Bow Valley Square Three
255 - 5 Ave. S.W.
Box No. 9570
Calgary, Alberta
T2P 3G6

(403)267-3500

Mr. Mike MacLennan
Harrisons and Crossfield (Canada) Ltd.
5711 - 1st St. S.E.
Calgary, Alberta
T2H 2H9

(403)253-7581

Mr. Bill Blaney
President
Inter-City Express
2655 Dillarton Hwy.
North Vancouver, B. C.
V7H 1B1

(604)929-5431

Mr. Gerry Gray
Sales Representative
Van Waters & Rogers Ltd.,
9800 Van Horne Way
Richmond, British Columbia
V6X 1W5

(604)273-1441

Mr. Ken Hawkins, Manager
Mr. Steve Diduck, Salesman
McKenzie and Feimman Ltd.
970 Malkin Avenue
Vancouver, British Columbia
V6A 2K8

(604)253-6335

Mr. Jim Philp
General Manager
Witco Chemicals
Suite 1, 5112 - 3rd St. S.E.
Calgary, Alberta
T2H 1J6

(403)258-5454

National Concrete Accessories Ltd.
7624 Winston Street
Burnaby, B.C.
V5A 2H4

Mr. John Ferguson
Product Specialist
Pounder Emulsions
1474 Wall St.
Winnipeg, Manitoba
R3E 2S4

(204)783-7197

Mr. Paul Cechmanek
President
United International Industries
Ltd.
5723 Burleigh Crescent, S.E.
Calgary, Alberta
T2H 1Z7

(403)253-9291

8.5 KNOWLEDGABLE INDIVIDUALS CONTACTED

Ontario

Mr. Hugh Blaine
Head, Maintenance Management
Maintenance Operations Office
Room 235, Central building
1201 Wilson Avenue
Downsview, Ontario
M3M 1J8

(416)248-3665

Mr. Howard Greenly
District Municipal Engineer
Ministry of Transportation and Communications
Box 5338
London, Ontario
NGA 5H2

Manitoba

Mr. Ray Van Cauwenberghe
Materials Engineer
Department of Highways
Winnipeg, Manitoba

(204)775-4503

Mr. J. Doerksen
Maintenance Engineer
Department of Highways
215 Garry Street
Winnipeg, Manitoba

(204)944-3778

Mr. Ron Gordon
District Engineer
Department of Highways
Winnipeg, Manitoba

(204)233-4957

Mr. Ted Clarke
Director of Streets & Transportation
City of Winnipeg
2nd Floor, 10 Fort Street
Winnipeg, Manitoba
R3C 1C4

(204)985-5285

Mr. Clayton Jackson
Highways Engineer
Operations
Department of Highways
16th Floor, 215 Garry Street
Winnipeg, Manitoba
R3C 3Z1

(204)944-3775

Mr. Obrey Hope
Regional Streets Engineer
Operations Department
City of Winnipeg
Winnipeg, Manitoba

(204)946-0193

Saskatchewan

Mr. Gary Heiman
Surfacing Engineer
Department of Highways
Regina, Saskatchewan

(306)565-4846

Mr. Tony Van Rosson
Supervisor, Industrial Section
Water Quality Division
Water Pollution Control Branch
Saskatchewan Environment
Regina, Saskatchewan

(306)565-6176

Mr. Mike Rychlo
Engineer
Saskatchewan Department of Environment
Regina, Saskatchewan

(306)565-6174

Alberta

Mr. Tony Desimon
Engineer
City of Calgary

(403)268-4933

Mr. Ed Belsheim
Director of Operations
Operations Branch
Regional Transportation
161 Transportation Building
9630 - 106 Street
Edmonton, Alberta

(403)427-3127

Mr. Neil MacKay
Traffic Safety Engineer
Alberta Transportation
Edmonton, Alberta

(403)427-7910

Mr. John Schmidt
Agriculture Reporter
Calgary Herald
Calgary, Alberta

Mr. B.P. Shields
Head, Transportation and Surface Water Engineering Dept.
Alberta Research Council
Edmonton, Alberta

(403)438-0777

Mr. K.O. Anderson
Professor, Civil Engineering
University of Alberta
Edmonton, Alberta

Dr. M.A. Ward
Professor and Dept. Head
Dept. of Civil Engineering
University of Calgary
Calgary, Alberta

(403)284-5821

Mr. R. Shaneman
Environmentalist
Manalta Coal Limited
734 - 7 Avenue S.W.
Calgary, Alberta
T2P 2M7

Mr. E. Polloway
Engineer
Pembina Pipelines Limited
734 - 7 Avenue S.W.
Calgary, Alberta
T2P 2M7

British Columbia

Mr. Bill Molnar
Surveys Supervisor
Engineering Branch
B.C. Ministry of Forests
1061 Fort Street
Victoria, British Columbia

(604)387-1258

Mr. Andrew Mitchell
Roads Administration
Ministry of Forests
1061 Fort Street
Victoria, British Columbia

(604)387-1258

Mr. Adam Kral
Logging Manager
Pacific Forest Products
Victoria, British Colubia

Mr. Jon Buckle
Maintenance Systems Engineer
Highways Operational Services
Division, Transportation and
Highways
3rd Floor, 940 Blanshard Street
Victoria, British Columbia

(604)387-1738

FERIC (Forest Engineering Research
Institute of Canada)
201-2112 W. Broadway
Vancouver, British Columbia
V6K 2C8

Mr. J.D. Anderson
Director, Farmland Resources Br.
Ministry of Agriculture and Food
808 Douglas Street
Victoria, B. C.

(604)387-5121

Mr. Ken Baker
Manager, Park Operations
Parks and Outdoor Recreation
Div.
Ministry of Lands, Parks and
Housing
Nootka Court
Victoria, B.C.

(604)387-5002

Northwest Territories

Mr. J. Bentley
Chief, Highways Divison
Department of Public Works
Government Northwest Territories
Yellowknife, Northwest
Territories

Paul Lind
Executive Director
Northwest Territories'
Association of Municipalities
Yellowknife, Northwest
Territories

8.6 ASSOCIATIONS CONTACTED

Mr. McCaffray
Ontario Good Roads' Association
P.O. Box 128
354 Talbot Street
St. Thomas, Ontario
V5P 3T7

(519)631-6820

Mr. Bill Yates
Executive Director
Roads and Transportation Association of Canada
1765 St. Laurent Boulevard
Ottawa, Ontario
K1G 3V4

(613)521-4052

Mr. McDonald
Ontario Road Builders' Association
325 Eddystone Avenue
Downsview, Ontario
M3N 1H8

(416)743-1242

Mr. Budgell
Executive Director
Road Bulders' and Heavy Construction Association of Manitoba
P.O. Box 86
St. James Station
Winnipeg, Manitoba
R3J 0H4

(204)772-3375

Manitoba Good Roads' Association
203 - 377 Henderson Highway
Winnipeg, Manitoba
R2K 2H2

(204)667-6585

Mr. Ed Amaolo
Safety Director
Saskatchewan Road Builders' Safety Association
11 Robinson Crescent
Regina, Saskatchewan
S4R 3R1

(306)545-0660

Union of Manitoba Municipalities
Box 536
Portage la Prairie, Manitoba
R1N 3B9

(204)857-8666

Mr. Wagg
Road Builders' and Heavy Construction Association of Saskatchewan
1939 Elphinstone Street
Regina, Saskatchewan
S4T 3N3

(306)525-0171

Mr. Wagg
Executive Director
Western Canada Road Builders' Association
P.O. Box 86
Regina, Saskatchewan
S4P 2Z5

(306)525-0171

Mr. McFarlane
Executive Director
Alberta Roadbuilders' Association
10147 - 119 Street
Edmonton, Alberta
T5K 1Z1

(403)488-3363

Mr. Jack Smith
General Manager
Yellowhead Interprovincial Highway
Association
614 McLeod Building
Edmonton, Alberta
T5J 0P1

(403)429-0444

Mr. Bob Nobel
Secretary Treasurer
Canadian Technical Asphalt
Association
P.O. Box 1387
Victoria, British Columbia
V8W 2W8

(604)385-8721

Mr. Derek Spooner
General Manager
British Columbia Road
Builders' Association
400 - 698 Seymour Street
Vancouver, British Columbia
V6B 3K7

(604)681-9251

GLOSSARY

GLOSSARY

Abrasion Apparatus	An apparatus designed to determine the wearing, grinding, or rubbing away of a substance by friction.
Absorption	The process of taking up or being taken up by another body (such as a sponge absorbs water).
Adsorption	The adhesion in an extremely thin layer of molecules (as of gases, solutes, or liquids) to the sufaces of solid bodies or liquids with which they are in contact.
Agglomeration	The action or process of collecting in a mass.
Aliphatic	Belonging to a group of organic compounds having an open-chain structure and consisting of the paraffin, olefin, and acetylene hydrocarbons and their derivatives.
Anionic Emulsion	An emulsion characterized by an active anion(s) (negatively charged ions).
Asphalt Road Primer	A heavy fuel oil whose viscosity is reduced to whatever is desired by adding petroleum distillate. Like road oil or spray oil, it is intended to prime gravel roads for receiving asphalt, and is straight-sprayed and left in the open.
Base Exchange	An electrochemical exchange of bases (molecules or ions able to take up a proton from an acid or substances able to give up an unshared pair of electrons to an acid).
Biodegradable	Capable of being broken down, especially into harmless products, by the action of living organisms (as microorganisms).
Bituminous	Containing much organic or at least carbonaceous matter, mostly in the form of the tarry hydrocarbons which are usually described as bitumen.
Bunker "A"	The lightest bunker oil produced with the least asphalt content and the most volatile components of the bunker oils. It is still a heavy oil in comparison to other petroleum products.

GLOSSARY (continued)

Bunker "B"	A slightly lighter oil than Bunker "C", meaning that its volatile components leave a little faster, but still a very heavy oil, as it is the dregs from the refining process.
Bunker "C"	The heaviest viscosity oil that refineries produce, with an asphalt content varying between 7 and 25%.
Capilliary Action	Action resulting from surface tension of a liquid, (such as water).
Cationic Emulsion	An emulsion characterized by an active cation(s) (positively charged ions).
Coagulation	Becoming viscous or thickened into a coherent mass.
Crude Oil	Naturally occuring unrefined oil as it comes from the wells. Varies widely in chemical composition, especially in its hydrocarbon content. Viscosity can vary greatly along with naturally occuring impurities such as sulphur.
Decant Oil	A fluxed oil which is the heaviest oil from the cracking process, but a lighter oil compared to bunker oil, equivalent to a furnace fuel or stove oil.
Deliquescent	Capable of becoming liquid by the absorption of water from the air.
Dissolution	The act or process of passing into solution or being dispersed.
DL 10 Dust Oil	A brand name for a heavy residual fuel oil that is diluted with straight-run heavy crude oil (as it comes from the well).
Electrical Conductivity	The reciprocal of electrical resistivity, electrical conductivity of soils is expressed in millisiemens per centimeter.
Entrapment	To catch or hold in.
Enzyme	Any of numerous complex proteins that are produced by living cells and catalyze specific biochemical reactions at body temperatures.

Exchangeable Cations	These are cations which are adsorbed onto the surface of soil colloids or parts of certain organic compounds in the soil (soil exchange complex). Some exchangeable cations are more easily displaced than other (adsorbtion affinity). Exchangeable cations are measured by displacing them with another cation on the soil exchange complex and then determining the concentration of displaced cations. Commonly used displacing reagents are ammonium acetate, sodium acetate and barium chloride. Exchangeable cations are expressed in millequivalents per 100 grams of soil.
Fines	Very small particles in a mixture of various sizes; by definitions those passing a No. 200 sieve (0.074 mm), consisting of silt and clay particles.
Float Gravel	Gravel that floats on the surface of a road, not being firmly contained.
Glyceride	An ester of glycerol, especially with fatty acids.
Heavy Metal	Metallic elements having a high density (>5 g/cm^3); toxic for the most part.
Hydrocarbon	An organic carbon (as acetylene or benzene) containing only carbon and hydrogen and often occuring in petroleum, natural gas, coal, and bitumens.
Hygroscopic	Having the property of readily absorbing moisture from the atmosphere.
LD_{50}	Lethal dose expected to kill 50% of a test group of organisms.
Leaching	Dissolving out by the action of a percolating liquid (such as rain water).
Liquid Limit	Water content of unconsolidated material at the point where it passes from a plastic solid to a turbid liquid as determined by standardized mechanical tests.

GLOSSARY (continued)

M.C.2	A heavy, very viscous, medium curing bunker oil with an arbitrary weight specification of "2"; the light end of the scale being 1 and the heavy end being 6. The particular base stock used here in mixing with the asphalt is naphtha. This is the same oil used to make cold mix asphalt.
M.C.O.	Any medium curing oil. This oil contains a selected grade of asphalt diluted with diesel fuel and medium curing refers to the length of time required for the base stock or solvent to evaporate and leave the hardened asphalt. (R.C. = rapid curing; S.C. = slow curing)
Micron	A micrometer, a unit of length equal to one millionth of a meter.
Organic	Of, relating to, or containing carbon compounds.
Oxidized	Chemically changed (a compound) by having the proportion of the electronegative part or charge (an element or ion) changed from a lower to a higher positive valence: having one or more electrons removed.
Palliative	Something that moderates the intensity of a condition (such as dustiness).
Pass	A single passage or movement of a man-made object (such as a water truck) over a place (such a gravel road).
pH	The negative logarithm of the effective hydrogen-ion concentration or activity in gram equivalents per liter. pH 7 is neutral, greater than 7 is alkaline, less than 7 is acidic. Soil pH - the degree of acidity or alkalinity expressed by the negative logarithm of the hydrogen-ion activity of a soil.
Physicochemical	Being physical and chemical; of or relating to chemistry that deals with the physicochemical properties of substances.
Plasticity Index	The numerical difference between the liquid limit and the plastic limit of a soil.

Plastic limit	Water content of unconsolidated material at the point where it passes from a plastic solid to a more or less rigid condition as determined by standardized tests.
Polychlorinated Biphenyl (PCB)	Any of several compounds that are produced by replacing hydrogen atoms in biphenyl with chlorine, have various industrial applications, and are pollutants which tend to accumulate in animal tissues.
Polycyclic Aromatic Hydrocarbons	Hydrocarbons having two or more fused rings in their molecular structure, at least one of which is a benzene ring.
Polymer	A chemical compound or mixture of compounds formed by polymerization and consisting essentially of repeating structural units.
Polynuclear Aromatics (PNAs)	General term for higher molecular weight aromatics which have the chemical structure of several benzene rings joined together. Found in automobile exhaust and asphalts, some exist in lubricating oils. These products are generally considered carcinogenic, although exposure from asphalts and oils is most likely minimal. - also called polyaromatic hydrocarbons (PAHs)
Primary Amine	A basic compound derived from ammonia by replacement of only one of the original hydrogens by one or more univalent hydrocarbon radicals.
Quaternary Ammonia	Any of numerous strong bases and their salts derived from ammonium by replacement of the hydrogen atoms with organic radicals and important especially as surface-active agents, disinfectants, and drugs.
Ravelling	To break up, separating the textures of a body (such as a road).
Waste oil	Used lube oil collected from service stations; possibly distilled once over, but not necessarily.
Re-refined oil	An oil that has been previously used but cleaned and refined to a level indistinguishable from virgin oil.

GLOSSARY (continued)

Road oil	A bunker oil sold by the refineries, also known as spray oil, which is intended to prime a gravel road in readiness for asphalt, but which varies greatly in asphalt content.
Sieve	A device with meshes or perforations through which finer particles of a mixture of various sizes are passed to separate them from coarser ones.
Silicosis	A condition of massive fibrosis of the lungs marked by shortness of breath and caused by prolonged inhalation of silica dusts.
Stratification	The act or process of layering; the state of being layered.
Sulfides	Compounds of sulfur analogous to an oxide or ether with sulfur in place of oxygen.
Sulfone Groups	Any of various compounds containing the sulfonyl group doubly united by its sulfur, usually with carbon.
Suppressant	Something that inhibits the development of a condition such as dustiness).
Surface Tension	A condition that exists at the free surface of a body (as a liquid) by reason of intermolecular forces about the individual surface molecules and is manifested by properties resembling those of an elastic skin under tension.
Surfactant	A surface-active substance (as a detergent).
Tight Bladed	Bladed such that the aggregate is packed or compressed to the maximum possible limit.
Trophic Level	One of the hierarchical strata of a food web characterized by organisms which are the same number of steps removed from the primary producers.
Turbidity	Thickness or opaqueness due to suspended sediments.
Used Transformer Oil	Oil used previously in transformers as a heat exhange medium. Often very high in PCB's, making it environmentally hazardous.

Vapor Pressure	The pressure exerted by a vapor that is in equilibrium with its solid or liquid form.
Viscosity	The property of a fluid or semifluid that enables it to develop and maintain an amount of shearing stress dependent upon the velocity of flow and then to offer continued resistance to flow; the ratio of the tangetial frictional force per unit area to the velocity gradient perpendicular to the direction of flow of a liquid - called also coefficient of viscosity.
Viscosity Index	An arbitrary number assigned as a measure of the constancy of the viscosity of a lubricating oil with change of temperature with higher numbers indicating viscosities that change little with temperature.
Wetting Agent	A substance, usually fluid, introduced into another liquid in order to reduce surface tension of the latter.
Windrow	A long low ridge of road-making material scraped to the side of a road.

ROAD DUST SUPPRESSION IN NORTHERN AND WESTERN CANADA

MANUAL OF RECOMMENDED PROCEDURES

FOR

ENVIRONMENT CANADA
ALBERTA ENVIRONMENT
MINISTRY OF ENVIRONMENT, BRITISH COLUMBIA
MANITOBA ENVIRONMENT
NORTHWEST TERRITORIES ENVIRONMENTAL SERVICES

MAY, 1982

TECHMAN ENGINEERING LIMITED

CALGARY, ALBERTA

EXECUTIVE SUMMARY

This manual presents the findings of the Review of Recommended Procedures step of the Road Dust Suppression in Northern and Western Canada study. The study was commissioned by the Federal Environmental Protection Service in association with the Environment Departments of Alberta, British Columbia, Manitoba and Northwest Territories.

MANUAL OBJECTIVES

The specific objectives of this manual are to:

- o identify road dust suppressant alternatives suitable for application in northern and western Canada;
- o identify environmental implications of road dust suppressant alternatives;
- o identify preferred application methods of road dust suppressant alternatives; and
- o develop a reference document which may be used by field personnel to select, apply and test dust control alternatives in an environmentally acceptable manner.

Information addressing the objectives was collected primarily through a literature search and interviews with government environment and transportation officials, road dust suppressant suppliers and transportation associations. The main findings of the study are summarized in the following sections.

ROAD DUST GENERATION AND CONTROL ALTERNATIVES

Road dust is generated by passing vehicles in three ways, vortex entrainment, slippage entrainment and saltation and creep of larger particles. Slippage entrainment is responsible for over 90 percent of road dust generated. Slippage entrainment refers to the suspension of road materials in the contact zone between the vehicle tire and the road surface.

Road dust may be suppressed on minor roads in three basic ways; reducing speed limits, paving, and application of road dust suppressants. The applicaton of suppressants is the most popular way of reducing dust on low traffic volume roads.

There are four primary types of suppressants; water and wetting agents; deliquescent and hygroscopic chemicals, organic non-bituminous binders; and petroleum based suppressants.

ROAD DUST CONTROL OBJECTIVES

A successful dust control program requires baseline information on the impacts of road dust in given areas. Having identified the impacts, the duration, degree and environmental effects of road dust control may be identified.

Road dust will affect road safety, aesthetics, vegetation, soils and aquatic resources. The adoption of a road dust control program in an area is dependent on the degree of adverse impact as evaluated by transportation personnel. Road dust control may be either short-term or long-term and the degree of dust control may be total or to acceptable safety levels.

SELECTION OF ROAD DUST SUPPRESSANTS

The selection of a suppressant for use in a given jurisdiction is based on three main criteria: the objectives of the program; site specific conditions associated with the road in question; and environmental and social implications of the suppressant.

Site specific conditions affecting suppressant selection include climate, road composition and location of sensitive areas. The environmental and social implications of the suppressant to be considered are the effects of the suppressant on roadside residents, soil, vegetation and water.

SUPPRESSANT APPLICATION AND MAINTENANCE

Optimum dust suppression depends on a well constructed surface course, adherance to suppressant manufacturer's application instructions and proper road maintenance.

Most road dust suppressants available in northern and western Canada require two applications per suppression season.

ROAD DUST SUPPRESSION IN NORTHERN AND WESTERN CANADA

MANUAL OF RECOMMENDED PROCEDURES

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CHAPTER 1

MANUAL OBJECTIVES AND ORGANIZATION

CHAPTER 1

MANUAL OBJECTIVES AND ORGANIZATION

1.1 INTRODUCTION

The purpose of this manual is to address the technical, environmental and economic issues faced by field personnel involved with road dust control programs. Special emphasis is given to the practical aspects of road dust suppression, specifically, selection, application and testing of road dust suppressants. The use of suppressants on minor roads is recognized as the most cost-effective method of controlling dust. This manual was commissioned by the Federal Environmental Protection Service in association with the Environment Departments of Alberta, British Columbia, Manitoba and Northwest Territories.

1.2 MANUAL OBJECTIVES

The specific objectives of this manual are to:

- o identify road dust suppressant alternatives suitable for application in northern and western Canada;
- o identify environmental implications of road dust suppressant alternatives;
- o identify preferred application methods of road dust suppressant alternatives; and
- o develop a reference document which may be used by field personnel to select, apply and test dust control alternatives in an environmentally acceptable manner.

1.3 MANUAL ORGANIZATION

This manual is divided into five chapters and three appendices. Chapter two explains how road dust is generated and the dust control alternatives available. Chapters three to five discuss why dust should or

should not be controlled and the selection and application of a road dust suppressant. The appendices provide background information on dust suppressants and field testing methods.

1.4 MANUAL LIMITATIONS

This manual as presented is meant to provide general information and guidelines on road dust and road dust control in northern and western Canada. The size of the study area does not allow a transportation district by transportation district evaluation within this report. Site specific conditions should be evaluated by field personnel in a particular area and a road dust control program developed based on the findings. Site specific information has been included in the report but for example purposes only.

Information on dust suppressants available in northern and western Canada has been included throughout this manual. The suppressant information is based on literature and interviews with government, industry and suppressant suppliers. However, all information regarding suppressant properties, availability, costs and application procedures should be double checked with the suppliers listed, before any control decisions are made.

CHAPTER 2

ROAD DUST GENERATION AND CONTROL ALTERNATIVES

CHAPTER 2

ROAD DUST GENERATION AND CONTROL ALTERNATIVES

2.1 ROAD DUST GENERATION

Road dust is generated by passing vehicles in three ways:

- vortex entrainment;
- slippage entrainment; and
- saltation and creep of larger particles.

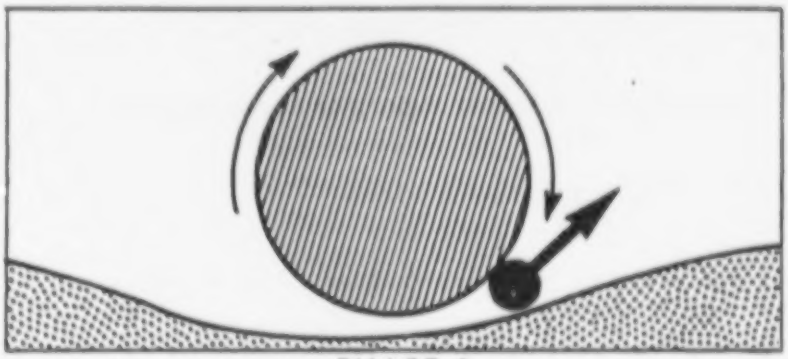
Vortex entrainment refers to a passing vehicle compressing and expanding air as it travels over a road surface. The compression and expansion serves to pump dust into the air.

Slippage entrainment refers to the suspension of material in the contact zone between the tire of the vehicle and the road surface. Slippage entrainment occurs in three phases and is responsible for approximately 90 percent of road dust generated by a passing vehicle;

- phase 1 - as the wheel approaches, the particle is forced forward and out with an abrading effect. (at this point vortex entrainment is also involved);
- phase 2 - when the vehicle is directly overhead, the particle is forced downward with a crushing effect; and
- phase 3 - when the vehicle leaves, the particle is forced backward and out with an abrading effect (saltation and creep of aggregate also involved here).

Figure 2-1 illustrates the three phases of slippage entrainment.

Saltation and creep of large aggregate particles also contribute to road dust generation. Saltation describes the process by which large aggregate particles suspended by slippage entrainment strike and suspend



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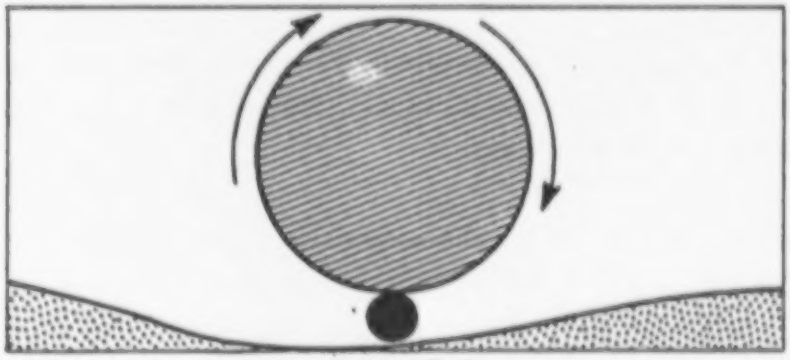
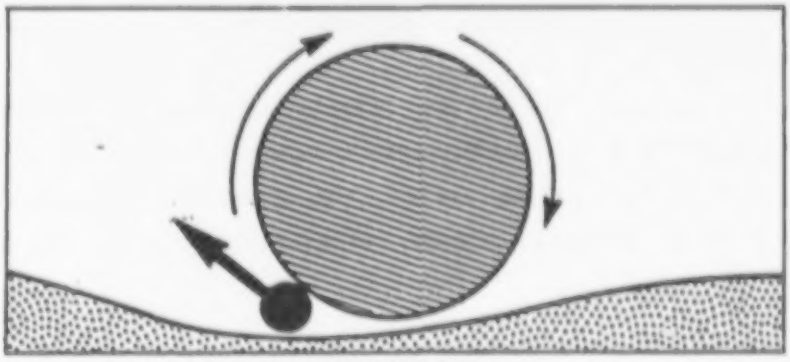


PHASE 2



PHASE 3

FIGURE 2-1

ACTION OF TIRES ON SOIL PARTICLE

(Sutton 1974)

PREPARED BY
Tecknoma
Engineering
Ltd.

other road surface particles. Surface creep refers to the rolling of large heavy particles along the road surface. These large particles are not suspended into the air by the impact of a saltating particle.

The rate and amount of road dust generated by the above three mechanisms, may be affected by the following factors;

- vehicle speed;
- number of wheels/vehicle;
- particle size distribution of road surface;
- surface moisture index;
- vehicle weight;
- vehicle cross section;
- tire width;
- tire design;
- length of unpaved road; and
- design of roadway.

There are three important sizes of road dust:

- > 10 microns-respresents large particles suspended by a moving vehicle, the largest of which are capable of damaging or breaking windshields, headlights or automobile trim;
- > 2 microns but < 10 microns-represents visible suspended dust particulates; and
- < 2 microns-comprises particulates which have the potential for maximum deposition in the lungs.

The size of road dust particles suspended directly affects the rate the particle falls and the distance travelled by a particle from the original suspension point. Dust data collected along roadways, has shown that the majority of road dust falls within 30 metres of the centreline.

2.2 ROAD DUST SUPPRESSION ALTERNATIVES

Road dust can be reduced in three basic ways:

- reducing speed limits;
- paving; and
- application of road dust suppressants.

2.2.1 Reducing Speed Limits

Road dust generated by vehicles has been shown to be proportional to vehicle speed (Roberts et al. 1979). Thus, lowering the speed limits on an unpaved road will reduce dust generated by traffic on the road. To a lesser degree, the number of wheels and weight of a vehicle also influence the amount of dust generated. Theoretically, a 66 percent reduction in the level of dust could be achieved solely by reducing speed limits from 50 km/hr to 17 km/hr (Roberts et al. 1979).

The monetary costs of establishing traffic controls are negligible, but the social costs may be significant. Social costs are reflected through increased travel time of personal and commercial vehicles. The environmental impact of traffic controls is nil.

2.2.2 Paving

The class and frequency of traffic on unpaved roads determines the methodology used to control dust generation. Paving of roads indicates a high frequency of personal and commercial traffic. Paving includes the use of a variety of surfacing materials. Three general types of pavement are:

- bituminous concrete;
- concrete; and
- chip seals.

Roads constructed with bituminous concrete and concrete surfaces are designed to support heavy traffic. Because of their high initial cost, these pavements are not generally used to surface minor roads. Chip seal surfaces, also called macadam, consist of one to three layers of aggregate and asphalt. The asphalt is sprayed over each aggregate layer, top-dressed with a covering of smaller stones and compacted. Finished chip seals are from one to four centimetres thick.

No adverse environmental impacts have been associated with paving strategies employing prudent application procedures.

2.2.3 Road Dust Suppressants

The application of road dust suppressants is the most cost-effective method of allaying dust on minor roads and is the focus of this manual. Several categories of dust suppressants are available. The four primary categories which may be used on unpaved roads are:

- o fresh or salt water in combination with wetting agents;
- o deliquescent and hygroscopic chemicals;
- o organic non-bituminous binders; and
- o petroleum derived binders.

Table 2-1 identifies the primary road dust suppressant alternatives available in northern and western Canada by category.

Water and Wetting Agents As a dust suppressant, water is effective over a comparatively short period of time, suppressing dust by weighing it down and attracting it with capillary moisture. Wetting agents aid in extending this effective period by inducing greater penetration and subgrade wetting. The subgrade acts as a moisture reservoir, replacing moisture lost through surface evaporation.

Table 2-1

ROAD DUST SUPPRESSANTS IDENTIFIED DURING THE STUDY BY CATEGORY

WATER AND WETTING AGENTS

Alchem 8808

DELIQUENSCENT AND HYGROSOPIC CHEMICALS

Calcium chloride
Sodium chloride
Salt Brines

ORGANIC NON-BITUMINOUS BINDERS

Modified Calcium Lignosulfonate
Sodium Lignosulfonate
Ammonium and Sodium Lignosulfonate
Read Chemicals Lignosulfonate
Spent Sulfite Liquor
DC-M18

PETROLEUM-DERIVED BINDERS

Used Oil, Waste Oil
Bunker Oil
DL-10
Emulsified Asphalt Primer
Coherex
Slow Curing Liquid Asphalt, SC30
Liquid Asphalt, MC30
Emulsified Asphalt SS1
Asphalt Road Primer
Decant Oil
Re-refined Oil
Heavy Crude Oil

Deliquescent and Hygroscopic Chemicals These chemicals attract water vapour from the atmosphere and hold it strongly, thereby maintaining a film of water that attracts dust particles. However, these chemicals are only effective if present in sufficient quantities and if the relative humidity is high enough to permit water absorption. As these chemicals are water soluble, they are easily leached from the road surface during heavy rains. Calcium chloride is the most common dust suppressant in this category.

Organic Non-bituminous Binders These binders are organic products and by-products that physically bind the soil particles together, or physically adhere to individual soil particles, weighing them down and causing agglomeration. The products available are generally biodegradable and do not appear to be relatively hazardous to the environment when leached from the road surface. Lignosulfonate products are the most common dust suppressants in this category. These are composed of the by-product wastes of the sulfite wood-pulping process.

Petroleum-derived Binders These binders agglomerate the soil particles and are generally not water-soluble. A broad range of petroleum products have been used for dust suppression, ranging from used lubricating oils to emulsified asphalt.

The efficiency of any dust suppressant depends upon:

- soil properties of the road;
- construction of the road;
- method and frequency of suppressant application;
- type and volume of vehicular traffic; and
- local weather conditions.

The planning of a road dust control program and the selection of a dust suppressant most effective for a particular area is the subject of the rest of this manual.

CHAPTER 3

ROAD DUST CONTROL OBJECTIVES

CHAPTER 3

ROAD DUST CONTROL OBJECTIVES

3.1 INTRODUCTION

To have a successful road dust control program, the objectives of the program must be identified at the outset. To identify the objectives the following questions must be answered:

1. Is dust control needed?
2. Where should road dust be suppressed?
3. How long must road dust be controlled?
4. To what degree should road dust be controlled?
5. What are the environmental consequences of road dust control?

3.2 DETERMINING THE NEED FOR ROAD DUST CONTROL

To identify whether road dust control is needed, a look at the impacts of road dust is required. In general the purpose of a road dust control program is to prevent dust conditions from developing to a point where adverse environmental and social impacts are experienced.

Specific impact areas of road dust include:

- safety;
- vehicle maintenance;
- aesthetics;
- vegetation;
- soils; and
- aquatic resources.

With respect to safety, the loose surface aggregate of unpaved roads contributes to a loss of visibility, skidding and swaying of vehicles, less positive steering response, longer stopping distance and broken windshields from flying rocks.

Roadside aesthetics are affected in three principal ways by road dust. Road dust can reduce the enjoyment of travel and scenery, lower property values and increase cleaning costs.

Road dust may affect vegetation by increasing heat absorption and reducing transpiration causing a heat build up in the leaf. This heat build up may result in the leaf dying and, taken to extremes, the whole plant may die.

Soil characteristics, such as pH, electrical conductivity and nutrient relationships, may be changed by road dust. Positive or negative changes in soil conditions may occur depending on the characteristics of the road dust.

Aquatic systems, specifically plants and fish may be affected adversely by road dust if sufficient amounts are deposited in waterbodies. The dust can cover fish rearing areas and fish food sources reducing reproduction and increasing starvation.

The degree of road dust impacts varies depending on:

- o the amount of dust generated;
- o the type and number of vehicles using the road;
- o location of road side development; and
- o the type of natural roadside environment.

3.3 SELECTION OF ROAD DUST CONTROL AREAS

The adoption of road dust control programs for a specific road section depends on field personnel evaluating the degree of environmental and social impact (sometimes based on citizens complaints). In general, the level of dust control is based on road class, average daily traffic and the location of:

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- residences;
- commercial businesses;
- school zones and playground zones;
- hospitals, churches and community halls;
- rest areas, points of interest, parks with tables and cemetaries;
- stop signs;
- uncontrolled intersections;
- railway crossings;
- orchards and vineyards; and
- heavy truck traffic.

Table 3-1 is an example of the British Columbia Ministry of Highways Dust Control Level of Service evaluation procedure.

3.4 DURATION OF ROAD DUST CONTROL PROGRAM

Dust suppression programs are either short-term or long-term. Short-term dust suppression programs are generally from one to seven days in duration and are required for such things as special community events, oil rig moves and mining test pit excavation haulage.

Long-term dust suppression is generally carried on throughout the summer season, from June through September in northern and western Canada. Long-term dust suppression is often required along well travelled roads, industrial haul routes and at recreation areas. In vacation areas, dust suppression may only be required during the height of the season.

3.5 DEGREE OF ROAD DUST CONTROL

The degree of dust suppression also falls into two categories, total dust control or acceptable dust control. Total dust control may be defined as attempting to eliminate as much dust as is possible. With the exception of water supply areas, total dust control is rarely required. In total dust control areas, paving may be warranted.

Acceptable dust control is most commonly defined in terms of safety. The maximum allowable dust condition which allows safe vehicular travel is deemed acceptable dust control. Although this condition may not tot-

Table 3-1

British Columbia Ministry of Highways

Dust Control Level of Service

TRAFFIC VOLUME ADT.	RESIDENCES	COMMERCIAL BUSINESS	SCHOOL ZONES & PLAYGROUND ZONES	HOSPITALS CHURCHES COMMUNITY HALLS	REST AREAS; STOP OF INTEREST; PARKS WITH TABLES; CEMETARIES	STOP SIGNS	RAILWAY CROSSINGS	ORCHARDS AND VINEYARDS (NOTE 1)	HEAVY TRUCK TRAFFIC
5000 1000	BUILDING WITHIN 100 METRES OF CENTRELINE OF ROAD 160 METRE STIP. IF 5 OR MORE SITES PER KM THEN CONTINUOUS STRIP.		STRIP TO BE FROM 60 METRE BEFORE SIGNS.	BUILDING WITHIN 100 METRES OF CENTRELINE OR ROAD. 160 METRE STRIP.	LENGTH OF PROPERTY OR 160 METRE WHICHEVER IS GREATER.	STOP SIGNS ON THIS CLASS OF ROAD. 60 METRE STRIP LEADING UP TO STOP SIGN.	A 160 METRE STRIP ON EACH SIDE OF THE CROSSING	10 TREES OR MORE WITHIN 60 METRES OF THE CENTRELINE OF THE ROAD. STRIP LENGTH SAME AS ORCHARD FRONTAGE.	IF MORE THAN 20% OF THE TRAFFIC IS HEAVY COMMERCIAL AND THE SURFACE MATERIAL IS SUCH AS TO CAUSE A HAZARDOUS DUST PROBLEM, APPLY A CONTINUOUS STRIP NOT TO BE DONE AUTOMATICALLY ON ALL INDUSTRIAL ROUTES
1000 500									
500 100	BUILDING WITHIN 50 METRES OF CENTRELINE OF ROAD 160 METRE STRIP. IF 5 OR MORE SITES PER KM THEN A CONTINUOUS STIP.							10 TREES OR MORE WITHIN 30 METRES OF THE CENTRELINE OF THE ROAD STRIP LENGTH SAME AS ORCHARD FRONTAGE.	
100 10						NIL	NIL, UNLESS SEVERE SIGHT DISTANCE RESTRICTIONS EXISTS.		
10 0	NIL		NIL					NIL	NIL

1. No Dust Control is to be given to Forage Crops.

ally satisfy all aesthetic concerns, it likely represents the best solution, of maintaining safety while permitting longer suppressant life before renewed application.

3.6 ENVIRONMENTAL CONSEQUENCES OF ROAD DUST CONTROL

The fact that there will be a continuing need to reduce road hazards ensures that the suppression of dust on unpaved roads, both public and private, by one method or another is inescapable. However, the environmental consequences of road dust suppressants must be evaluated prior to application. The environmental impact of suppressant use may in some cases cause more damage than the dust it is meant to suppress. For this reason a "no suppressant" alternative should always be considered when planning a road dust control program

CHAPTER 4

SELECTION OF ROAD DUST SUPPRESSANTS

CHAPTER 4

SELECTION OF ROAD DUST SUPPRESSANTS

4.1 INTRODUCTION

As identified in Chapter 2 there are four basic types of road dust suppressants available on the market today:

- o water and wetting agents;
- o deliquescent and hygroscopic chemicals;
- o organic non-bituminous binders; and
- o petroleum-based suppressants.

All of the four primary types of suppressants must appear to satisfy to some degree the following basic requirements:

- o must be environmentally compatable;
- o must be easily applied with common road maintenance equipment;
- o must be a workable material lending itself to standard maintenance methods of blading on gravel surfaces;
- o must provide reasonable retention and reduce or eliminate subsequent applications; and
- o must provide little loss of riding quality.

The selection of a suppressant for use in a given jurisdiction is generally based on three criteria:

- o objectives of road dust control program (as discussed in Chapter 3);
- o site specific conditions associated with the road in question; and
- o environmental and social implications of the suppressant.

This chapter is dedicated to discussing site specific considerations, and environmental and social implications affecting road dust suppressant choice. It is intended that manual users supplement the information in this chapter with application and pricing details from

suppressant suppliers. Final selection should be based on the user's objectives, bearing in mind the environmental and social considerations discussed.

4.2 SITE-SPECIFIC CONSIDERATIONS

Information on climate, road characteristics and sensitive areas needs to be acquired for any area chosen for dust suppression. Depending on these factors, more than one dust suppressant may be required.

4.2.1 Climate

Temperature, relative humidity and precipitation all affect dust suppressant selection.

Temperature and relative humidity data are important in selecting a suppressant which will work in a particular area. Deliquescent chemicals, such as calcium chloride, work better as dust suppressants as relative humidity increases. The relative humidity refers to the amount of water available in the air to be absorbed by the calcium chloride. The higher the relative humidity, the more water available, the more efficient the calcium chloride or other deliquescent chemical.

Precipitation is another factor which influences the selection of dust suppressants and their application to road surfaces. Suppressants applied in high rainfall areas, if readily water-soluble, will run off and leach into the surrounding roadside environment. This problem is increased in areas of high intensity storms. To reduce suppressant loss from the roads, rainfall areas, suppressants which are less water soluble should be used.

Another way to reduce suppressant loss in high rainfall areas is to mix them into the road surface as an in-depth application. Surface application of suppressants leaves them exposed on the road surface, enhancing the possibility of runoff particularily during product

curing. In-depth application of suppressants mixes the suppressant with the road aggregate and reduces the runoff potential.

Table 4-1 summarizes the climatic limitations of road dust suppressants available in northern and western Canada.

4.2.2 Road Characteristics

Road characteristics that warrant consideration in dust suppressant selection include surface course materials and traffic volumes. Some agency suppliers may also require information on plasticity index and liquid limits to determine the suitability of particular suppressants. For surface course materials, the fraction passing a No. 200 sieve should ultimately not be greater than two-thirds the fraction passing a No. 40 sieve (Figure 4-1).

Total fines should range from 10 to 25% of surface course materials, although in parts of northern and western Canada this is not always possible. Fines are defined as those materials capable of passing through a No. 200 sieve. Also, the fraction passing a No. 40 sieve should have a liquid limit not greater than 35 and a plasticity index not less than 4 or greater than 9. Table 4-1 provides optimum road surface gradations by suppressants.

Traffic is important in dust suppressant selection, since greater traffic volumes necessitate dust suppressants that can remain effective under these conditions. The type of vehicles travelling a particular area is also important. These factors are expressed as average daily traffic (A.D.T.) and percent commercial.

Table 4-1 summarizes road characteristic limitations by suppressant.

4.2.3 Sensitive Areas

Environmentally sensitive areas which warrant special attention include streams and waterbodies, areas with a high water table and other water

Table 4-1 Dust Suppressant Information Matrix[1]

Suppressant	Application Life[2]	Climatic Limitations	Optimum Road Surface Gradation (% Fines)	Comments
WATER AND WETTING AGENTS				
Water (Fresh or Saltwater)	Short-term	Drier climates require considerably more frequent applications.	10-25% Fines	Short-term life limits usefulness for public road dust suppression.
Alchem 8808	Short-term	Drier climates require more frequent applications but not as much as for water alone.	10-25% Fines	Short-term life limits usefulness for public road dust suppression.
DELIQUESCENT AND HYGROSCOPIC CHEMICALS				
Calcium Chloride	Long-term	Loses effectiveness in dry periods with low daily relative humidities. Minimum relative humidity required ranges with temperature from 20 to 40%. Easily leached from road in heavy rain.	10-15% Fines	Generally ineffective in surface courses with lower fines' contents.
ORGANIC NON-BITUMINOUS BINDERS				
Calcium Lignosulfonate	Long-term	Superior to calcium chloride in long dry periods. Leached from road in heavy rain but generally not as much as calcium chloride.	10-25% Fines	Dilution and application instructions must be strictly followed. Generally ineffective in surface courses with lower fines' contents.

Table 4-1 Dust Suppressant Information Matrix[1]

Suppressant	Application Life[2]	Climatic Limitations	Optimum Road Surface Gradation (% Fines)	Comments
DC-M18	Long-term	New product - initial results encouraging in both long dry periods and heavy rainfall.	10-25% Fines and up. Apparently effective in higher fines' contents.	New product still undergoing research.
PETROLEUM BASED SUPPRESSANTS				
Used oil, Waste oil	Long-term	Generally effective, regardless of climatic conditions. May pot-hole in wet periods.	10-25% Fines. High clay content may require greater applications.	Used oil use discouraged at the provincial level in western and northern Canada in favor of energy conservation and environmental protection.
Bunker oil	Long-term	Generally effective, regardless of climatic conditions. May pot-hole in wet periods and if cures hard.	10-25% Fines. High clay content may require greater applications.	May be difficult to rework surface course if cures hard.
DL-10	Long-term	Generally effective regardless of climatic conditions. May pot-hole in wet periods.	10-25% Fines. High Clay content may require greater applications.	Apparently remains reworkable.
Emulsified Asphalt Primer	Long-term	Generally effective regardless of climatic conditions. Cures hard and will pot-hole in wet periods if too many fines in road surface.	Best performance noted with low fines' and high sand content surface courses.	Cures hard, most likely difficult to rework surface course.

Table 4-1 Dust Suppressant Information Matrix[1]

Suppressant	Application Life[2]	Climatic Limitations	Optimum Road Surface Gradation (% Fines)	Comments
Coherex	Short to Long-Term	May be favoured in locations that are too dry for calcium chloride.	10-25% Fines	Contradictory results with use appear in the literature.
Slow Curing Liquid	Long-Term	Generally effective regardless of climatic conditions. May pot-hole in wet weather	10-25% Fines	Hardened crust makes road difficult to rework and promotes pot holing.
Liquid Asphalt, MC30	Long-Term	Generally effective regardless of climatic conditions. May pot-hole in wet weather	10-25% Fines	Hardened crust makes road difficult to rework and promotes pot holing.
Emulsified Asphalt, SS1	Long-Term	Generally effective regardless of climatic conditions. May pot-hole in wet weather	10-25% Fines	Hardened crust makes road difficult to rework and promotes pot holing.
Asphalt Road Primer	Long-Term	Generally effective regardless of climatic conditions. May pot-hole in wet weather	10-25% Fines	Hardened crust makes road difficult to rework and promotes pot holing.

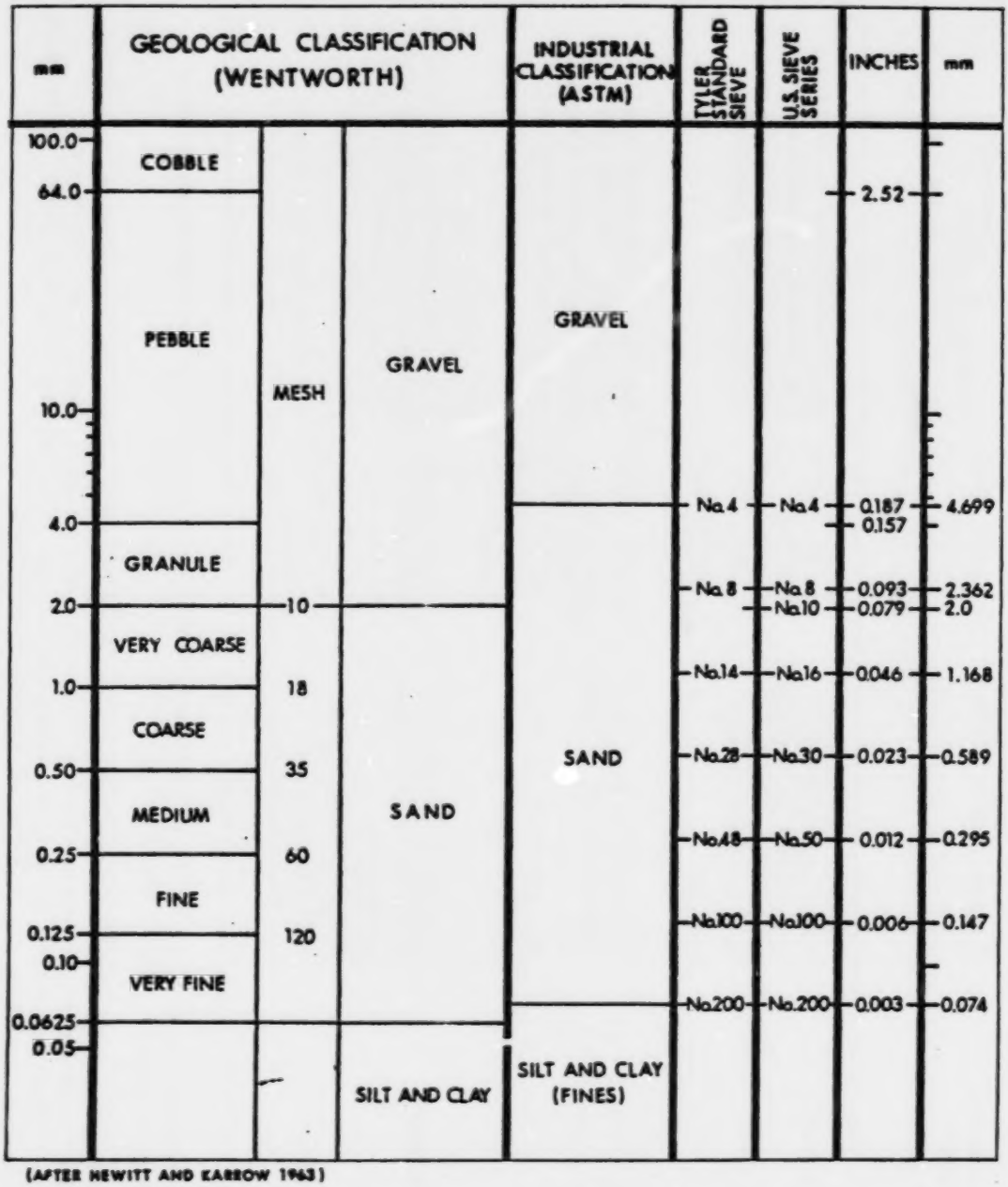
Table 4-1 Dust Suppressant Information Matrix[1]

Suppressant	Application Life[2]	Climatic Limitations	Optimum Road Surface Gradation (% Fines)	Comments
Decant Oil	Long-Term	Generally effective regardless of climatic conditions. May pot-hole in wet weather	10-25% Fines High clay content may require greater applications	Use discouraged in northern and western Canada in favour of energy conservation and environmental protection.
Re-refined Oil	Long-Term	Generally effective regardless of climatic conditions. May pot-hole in wet weather	10-25% Fines High clay content may require greater applications	Use discouraged in northern and western Canada in favour of energy conservation and environmental protection.
Heavy Crude Oil	Long-Term	Generally effective regardless of climatic conditions. May pot-hole in wet weather	10-25% Fines High clay content may require greater applications	Use discouraged in northern and western Canada in favour of energy conservation and environmental protection.

NOTES:

1. All dust suppressants, especially Water and Wetting Agents, may require more frequent applications with higher traffic volumes and/or heavier vehicles.

2. Short-term application life refers generally to less than one week of initial extended dust control being attainable following suppressant application, under most common conditions. Long-term application life refers generally to several weeks of initial extended dust control being attainable following suppressant application, under most common conditions.



(AFTER HEWITT AND KARROW 1963)

FIGURE 4-1

COMMON SIEVE SIZES OF GEOLOGICAL & INDUSTRIAL SAND AND GRAVEL CLASSES

PREPARED BY:
Techmos Engineering Ltd.

supply areas. On roads, located near environmentally sensitive areas, alternative suppressants that are environmentally safe should be used.

4.3 ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

Potential environmental and social implications of road dust suppression alternatives are identified in Table 4-2. The environmental and social consequences of a suppressant must be evaluated prior to application. The environmental impact of suppressant use may in some cases cause more damage than the dust it is intended to control. For this reason a "no suppressant" alternative should always be considered when planning a road dust control program.

Table 4-2 **Environmental and Social Considerations for Dust Suppressants**

Suppressant	Environmental Considerations	Social Considerations
NO SUPPRESSION	o Dust may affect vegetation by increasing heat absorption and reducing transpiration causing a heat build up in the leaf. o Dust affects sphagnum moss, reducing water content, chlorophyll content and carbon uptake and increasing temperature, mineral ion concentration and pH in plant water. o pH, electrical conductivity and nutrient relationships of soil may be affected either positively or negatively depending on elements contributed by road dust. o Road dust may affect aquatic plants and fish by contributing to increased sedimentation.	o Increased accident potential due to loss of visibility skidding and swaying of vehicles, less positive steering response and broken windshields. o Reduction in the quality of life. o Lowering of property values. o Increased cleaning costs. o Retention of particles (less than 2 microns) in lungs.
TRAFFIC CONTROLS	o None Apparent.	o Travel time loss.
PAVING	o None Apparent.	o None apparent.
WATER AND WETTING AGENTS		
Water (Fresh or Salt)	o Salt water may have impacts similar to calcium chloride	o Salt water may have impacts similar to calcium chloride o Short-term dust suppressant life.
Alchem 8808	o Apparently incurs none of the environmental problems often associated with waste-oil use.	o None apparent - short-term dust suppressant life

Suppressant	Environmental Considerations	Social Considerations
WATER AND WETTING AGENTS (continued)		
Alchem 8808 (continued)	o Precautions for human contact suggest that some environmental hazards may exist.	
DELIQUESCENT AND HYGROSCOPIC CHEMICALS		
Calcium Chloride	o Generally non-toxic due to rapid dissolution in the environment. o Toxic to some plants such as fruit trees.	o May be concentrated in ground-water or wells, causing hardening of water. o May cause elevated chloride levels in drinking water. o Use near fruit tree orchards may warrant initial testing due to potential toxicity to fruit trees. o Surface "crust" may be slippery in wet weather. o Possible corrosion of vehicles.
ORGANIC, NON-BITUMINOUS BINDERS		
Calcium Lignosulfonate	o Biodegradation slow - persistent in the environment. o Moderately toxic to rainbow trout.	o Molasses-like smell o Road surface may become slippery in wet weather. o Possible corrosion to vehicles
DC-M18	o Product is apparently completely biodegradable and none of the ingredients are considered toxic. o Initial tests indicate DC-M18 is non-toxic and non-acidic.	o No strong odor.
PETROLEUM-BASED SUPPRESSANTS		
Used Oil, Waste Oil	o Discouraged in northern and western Canada. o Used oil imposes a considerable environmental threat because of heavy metals (especially lead), P.N.A's and P.C.B.'s.	o Use of used oil for dust suppression has been discouraged at the provincial level due to economic and environmental concerns.

Suppressant	Environmental Considerations	Social Considerations
PETROLEUM-BASES SUPPRESSANTS (continued)		
Used Oil, Waste Oil (continued)	o Common contaminants are potentially very toxic.	
Bunker Oil	o Potential hydrocarbon contamination of nearby watercourses, and groundwater. o Full environmental implications of use not well researched. o Contains hydrocarbons that may be potentially toxic.	o Use of petroleum products for dust suppression is generally discouraged at the provincial level due to economic and environmental considerations. o Smell or appearance may be less desirable than other dust suppression alternatives.
DL-10	o Product generally remains in the roadbed. o Potential hydrocarbon contamination of local water bodies, particularily if applied excessively.	o Strength of odor unknown.
Emulsified Asphalt Primer	o Product generally remains in the surface course. o Potential hydrocarbon contination of local water bodies, particularily if applied excessively.	o Strength of odor unknown.
Coherex	o Apparently non-injurious to plant growth. o Some impacts have been noted in the U.S., details unavailable at time of printing.	o Strength of odor unknown. o Yellow colour only while products cures.

CHAPTER 5

SUPPRESSANT APPLICATION AND ROAD MAINTENANCE

CHAPTER 5

SUPPRESSANT APPLICATION AND ROAD MAINTENANCE

5.1 SURFACE COURSE PREPARATION

Optimum dust suppression depends on a well constructed surface course with good drainage characteristics and operators' adherence to manufacturer's application instructions for dust suppressants used. The following general guidelines should be followed when applying a road dust suppressant:

- Good ditching and grading to a firm surface with optimum crown is desired. However, the surface course must first be upgraded, either by reworking the old surface course or adding a new lift of aggregate. Reworking the present surface course is the recommended alternative in most cases. Application of the dust suppressant may begin at this point, with initial applications to the subgrade or windrows.

- Application of a new aggregate lift still requires that the old surface be repaired by ditching and grading. Depending on the manufacturer's directions, the dust suppressant may be applied on top of the old surface and mixed into the new lift or just applied to the surface.

- Final surface materials should be comprised of 10 to 15% fines and no gravels in excess of 2.5 cm diameter; however, in parts of northern and western Canada this may not be possible. If the fines content is over 25% the road surface tends to become impervious resulting in frost heave and consolidation problems. The final surface course should be shaped into an "A" crown with a fall of 4% (4 cm per metre).

- It is usually desireable to tight blade the final surface grade to ensure optimum roadbed performance and possibly prolong suppressant life.

- During suppressant application, surface course materials should be at or just slightly below optimum moisture levels to ensure suppressant penetration without any pooling or runoff.

5.2 SUPPRESSANT APPLICATION

Suppressant preparation procedures and application rates should follow suppliers' recommendations, although these factors can vary according to local experience. Preparation of a suppressant often involves dilution with an application medium, usually water. As described in Appendix 1, dilutions vary from 1:1 for lignosulfonates to as much as 1:2000 or more for wetting agents. General preparation procedures and application rates are presented in Table 5-1 and on the Dust Suppressant Information Sheets in Appendix 1.

Precautionary measures during application include leaving a small windrow (to be removed later) for blotting of thickly applied suppressants or keeping a grader nearby should mixing be required due to poor suppressant penetration.

Following application, compaction of the final road surface is recommended to ensure good compaction, penetration, and particle cohesion. This will generally increase roadbed performance and dust supressant life. Compaction can generally be attained by the use of a steel roller, a rubber-tired roller or commercial vehicles. If a suppressant is applied to a finished and compacted surface, then further compaction may not be necessary.

Some suppressants, such as lignosulfonates and petroleum emulsions, often take some time to set and may require traffic controls after application.

5.3 ROAD MAINTENANCE

A correctly applied dust suppressant will reduce general road maintenance requirements and result in savings in maintenance costs.

Table 5-1

Application Data For Most Common Dust Suppressants Available in Northern and Western Canada*

Suppressant	Application Range	Application Strength	Number of Applications
Water and Wetting Agents			
Alchem 8808	Add 2-3% concentration to water which would usually be applied. (0.5% Once base built-up)	-	Every 2-3 days
Deliquescent and Hygroscopic Chemicals			
Calcium Chloride	0.5-5.0 L/m^2	generally 35%	minimum of one application per season
Sodium Chloride	0.5-5.0 L/m^2	-	usually more than calcium chloride in same area
Salt Brines	0.5-5.0 L/m^2	Full Strength (>7% Calcium Chloride)	2 or more applications per season
Organic Non-Bituminous Binders			
Calcium Lignosulfonate	1.9-2.2L/m^2	1:1 water	minimum of one application per season
Sodium Lignosulfonate	1.9-2.2L/m^2	1:1 water	minimum of one application per season
Ammonium and Sodium Lignosulfonate	1.9-2.2L/m^3	1:1 water	minimum of one application per season
Read Chemicals Lignosulfonate	1-2% solid mixed into windrow	-	-
Spent Sulfite Liquor	1.9-2.2L/m^2	Full strength to 1:1 water	-
DC-M18	1$L/22-55m^2$	1 part in 85-100 parts water	2-3 applications/year

Table 5-1
(Continued)
Application Data For Most Common Dust Suppressants Available in Northern and Western Canada

Suppressant	Application Range	Application Strength	Number of Applications
Petroleum Based Suppressants			
Used Lubricating Oil, Waste Oil	1.1-1.7 L/m^2	-	2 applications first year 1-2 thereafter
Bunker Oil	1.1-1.3 L/m^2	-	-
DL-10	1.8L/m^2	-	3 in first season. 2 in each season thereafter
Emulsified Asphalt Primer	1.8L/m^2	-	1 application per year.
Coherex	2.0-3.0 L/m^2	1:4 water	-
Slow Curing Liquid Asphalt, SC30	1.35-1.65 L/m^2	-	minimum of one application first year
Liquid Asphalt, MC30	1.1-1.4 L/m^2	-	1 application per year
Emulsified Asphalt SS1	1.1-1.4 L/m^2	-	1 application per year
Asphalt Road Primer	1.1-1.4 L/m^2	-	-
Decant Oil	1.1-1.65 L/m^2	-	-
Re-refined Oil	1.1-1.65 L/m^2	-	-
Heavy Crude Oil	1.1-1.65 L/m^2	-	-

* Application ranges, application strength and number of applications as reported by transportation officials or suppliers for the study region.

However, a dust suppressant that is incorrectly applied may substantially increase maintenance costs. Examples include: the deep application of calcium chloride to roads with very plastic subgrades, leading to increased road instability and water retention problems; allowing a lignosulfonate application to cure too fast, resulting in a hard crust that promotes potholing and is slippery when wet; and an asphalt emulsion which is allowed to cure hard, causing severe potholing and not lending itself to road surface reworking.

Unless a deliquescent and hygroscopic suppressant, such as calcium chloride, is used under extremely dry conditions or the suppressant chosen is merely a wetting agent, road watering should not be necessary.

Most dust suppressants are reworkable unless otherwise stated by the supplier. Grading should be performed only when necessary, preferably when surface course materials are naturally moist. If necessary, grading may be performed on a dry surface course, but only following sufficient watering (such as 1500 L/km for a single-lane roadway). Grading under dry conditions is very difficult and can lead to increased losses of suppressant and fines due to dusting.

Grading should be performed at minimal depth, only deep enough to rework imperfections and allow the mixing in and reduction of float gravel. Grading should never be deeper than 10 cm to prevent excessive dilution of the suppressant. The 4% "A" crown should still be retained. The number of gradings necessary throughout the seasons is dependant on the desired level of maintenance and the roadbed performance.

Generally, two applications of a dust suppressant are required per season in northern and western Canada. Second applications are generally not as extensive as the original and usually involve one-half the original amount of suppressant. The second application is usually applied on top of the freshly graded damp surface course regardless of initial application procedures.

CHAPTER 6

SELECTED REFERENCES

CHAPTER 6

SELECTED REFERENCES

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GLOSSARY

GLOSSARY

Abrasion Apparatus	An apparatus designed to determine the wearing, grinding, or rubbing away of a substance by friction.
Absorption	The process of taking up or being taken up by another body (such as a sponge absorbs water).
Adsorption	The adhesion in an extremely thin layer of molecules (as of gases, solutes, or liquids) to the sufaces of solid bodies or liquids with which they are in contact.
Agglomeration	The action or process of collecting in a mass.
Aliphatic	Belonging to a group of organic compounds having an open-chain structure and consisting of the paraffin, olefin, and acetylene hydrocarbons and their derivatives.
Anionic Emulsion	An emulsion characterized by an active anion(s) (negatively charged ions).
Asphalt Road Primer	A heavy fuel oil whose viscosity is reduced to whatever is desired by adding petroleum distillate. Like road oil or spray oil, it is intended to prime gravel roads for receiving asphalt, and is straight-sprayed and left in the open.
Base Exchange	An electrochemical exchange of bases (molecules or ions able to take up a proton from an acid or substances able to give up an unshared pair of electrons to an acid).
Biodegradable	Capable of being broken down, especially into harmless products, by the action of living organisms (as microorganisms).
Bituminous	Containing much organic or at least carbonaceous matter, mostly in the form of the tarry hydrocarbons which are usually described as bitumen.
Bunker "A"	The lightest bunker oil produced with the least asphalt content and the most volatile components of the bunker oils. It is still a heavy oil in comparison to other petroleum products.

Bunker "B"	A slightly lighter oil than Bunker "C", meaning that its volatile components leave a little faster, but still a very heavy oil, as it is the dregs from the refining process.
Bunker "C"	The heaviest viscosity oil that refineries produce, with an asphalt content varying between 7 and 25%.
Capilliary Action	Action resulting from surface tension of a liquid, (such as water).
Cationic Emulsion	An emulsion characterized by an active cation(s) (positively charged ions).
Coagulation	Becoming viscous or thickened into a coherent mass.
Crude Oil	Naturally occuring unrefined oil as it comes from the wells. Varies widely in chemical composition, especially in its hydrocarbon content. Viscosity can vary greatly along with naturally occuring impurities such as sulphur.
Decant Oil	A fluxed oil which is the heaviest oil from the cracking process, but a lighter oil compared to bunker oil, equivalent to a furnace fuel or stove oil.
Deliquescent	Capable of becoming liquid by the absorption of water from the air.
Dissolution	The act or process of passing into solution or being dispersed.
DL 10 Dust Oil	A brand name for a heavy residual fuel oil that is diluted with straight-run heavy crude oil (as it comes from the well).
Electrical Conductivity	The reciprocal of electrical resistivity, electrical conductivity of soils is expressed in millisiemens per centimeter.
Entrapment	To catch or hold in.
Enzyme	Any of numerous complex proteins that are produced by living cells and catalyze specific biochemical reactions at body temperatures.

Exchangeable Cations	These are cations which are adsorbed onto the surface of soil colloids or parts of certain organic compounds in the soil (soil exchange complex). Some exchangeable cations are more easily displaced than other (adsorbtion affinity). Exchangeable cations are measured by displacing them with another cation on the soil exchange complex and then determining the concentration of displaced cations. Commonly used displacing reagents are ammonium acetate, sodium acetate and barium chloride. Exchangeable cations are expressed in millequivalents per 100 grams of soil.
Fines	Very small particles in a mixture of various sizes; by definitions those passing a No. 200 sieve (0.074 mm), consisting of silt and clay particles.
Float Gravel	Gravel that floats on the surface of a road, not being firmly contained.
Glyceride	An ester of glycerol, especially with fatty acids.
Heavy Metal	Metallic elements having a high density (>5 g/cm^3); toxic for the most part.
Hydrocarbon	An organic carbon (as acetylene or benzene) containing only carbon and hydrogen and often occuring in petroleum, natural gas, coal, and bitumens.
Hygroscopic	Having the property of readily absorbing moisture from the atmosphere.
LD_{50}	Lethal dose expected to kill 50% of a test group of organisms.
Leaching	Dissolving out by the action of a percolating liquid (such as rain water).
Liquid Limit	Water content of unconsolidated material at the point where it passes from a plastic solid to a turbid liquid as determined by standardized mechanical tests.

M.C.2	A heavy, very viscous, medium curing bunker oil with an arbitrary weight specification of "2"; the light end of the scale being 1 and the heavy end being 6. The particular base stock used here in mixing with the asphalt is naphtha. This is the same oil used to make cold mix asphalt.
M.C.O.	Any medium curing oil. This oil contains a selected grade of asphalt diluted with diesel fuel and medium curing refers to the length of time required for the base stock or solvent to evaporate and leave the hardened asphalt. (R.C. = rapid curing; S.C. = slow curing)
Micron	A micrometer, a unit of length equal to one millionth of a meter.
Organic	Of, relating to, or containing carbon compounds.
Oxidized	Chemically changed (a compound) by having the proportion of the electronegative part or charge (an element or ion) changed from a lower to a higher positive valence: having one or more electrons removed.
Palliative	Something that moderates the intensity of a condition (such as dustiness).
Pass	A single passage or movement of a man-made object (such as a water truck) over a place (such a gravel road).
pH	The negative logarithm of the effective hydrogen-ion concentration or activity in gram equivalents per liter. pH 7 is neutral, greater than 7 is alkaline, less than 7 is acidic. Soil pH - the degree of acidity or alkalinity expressed by the negative logarithm of the hydrogen-ion activity of a soil.
Physicochemical	Being physical and chemical; of or relating to chemistry that deals with the physicochemical properties of substances.
Plasticity Index	The numerical difference between the liquid limit and the plastic limit of a soil.

Plastic limit	Water content of unconsolidated material at the point where it passes from a plastic solid to a more or less rigid condition as determined by standardized tests.
Polychlorinated Biphenyl (PCB)	Any of several compounds that are produced by replacing hydrogen atoms in biphenyl with chlorine, have various industrial applications, and are environmental pollutants which tend to accumulate in animal tissues.
Polycyclic Aromatic Hydrocarbons	Hydrocarbons having two or more fused rings in their molecular structure, at least one of which is a benzene ring.
Polymer	A chemical compound or mixture of compounds formed by polymerization and consisting essentially of repeating structural units.
Polynuclear Aromatics (PNAs)	General term for higher molecular weight aromatics which have the chemical structure of several benzene rings joined together. Found in automobile exhaust and asphalts, some exist in lubricating oils. These products are generally considered carcinogenic, although exposure from asphalts and oils is most likely minimal. - also called polyaromatic hydrocarbons (PAHs)
Primary Amine	A basic compound derived from ammonia by replacement of only one of the original hydrogens by one or more univalent hydrocarbon radicals.
Quaternary Ammonia	Any of numerous strong bases and their salts derived from ammonium by replacement of the hydrogen atoms with organic radicals and important especially as surface-active agents, disinfectants, and drugs.
Ravelling	To break up, separating the textures of a body (such as a road).
Reclaimed oil	Lube oil reclaimed from service stations; possibly distilled once over, but not necessarily.
Re-refined oil	An oil that has been previously used but cleaned and refined to a level indistinguishable from virgin oil.

GLOSSARY (continued)

Road oil	A bunker oil sold by the refineries, also known as spray oil, which is intended to prime a gravel road in readiness for asphalt, but which varies greatly in asphalt content.
Sieve	A device with meshes or perforations through which finer particles of a mixture of various sizes are passed to separate them from coarser ones.
Silicosis	A condition of massive fibrosis of the lungs marked by shortness of breath and caused by prolonged inhalation of silica dusts.
Stratification	The act or process of layering; the state of being layered.
Sulfides	Compounds of sulfur analogous to an oxide or ether with sulfur in place of oxygen.
Sulfone Groups	Any of various compounds containing the sulfonyl group doubly united by its sulfur, usually with carbon.
Suppressant	Something that inhibits the development of a condition such as dustiness).
Surface Tension	A condition that exists at the free surface of a body (as a liquid) by reason of intermolecular forces about the individual surface molecules and is manifested by properties resembling those of an elastic skin under tension.
Surfactant	A surface-active substance (as a detergent).
Tight Bladed	Bladed such that the aggregate is packed or compressed to the maximum possible limit.
Trophic Level	One of the hierarchical strata of a food web characterized by organisms which are the same number of steps removed from the primary producers.
Turbidity	Thickness or opaqueness due to suspended sediments.
Used Transformer Oil	Oil used previously in transformers as a heat exhange medium. Often very high in PCB's, making it environmentally hazardous.

Vapor Pressure	The pressure exerted by a vapor that is in equilibrium with its solid or liquid form.
Viscosity	The property of a fluid or semifluid that enables it to develop and maintain an amount of shearing stress dependent upon the velocity of flow and then to offer continued resistance to flow; the ratio of the tangetial frictional force per unit area to the velocity gradient perpendicular to the direction of flow of a liquid - called also coefficient of viscosity.
Viscosity Index	An arbitrary number assigned as a measure of the constancy of the viscosity of a lubricating oil with change of temperature with higher numbers indicating viscosities that change little with temperature.
Wetting Agent	A substance, usually fluid, introduced into another liquid in order to reduce surface tension of the latter.
Windrow	A long low ridge of road-making material scraped to the side of a road.

APPENDIX 1

DUST SUPPRESSANT INFORMATION SHEETS

APPENDIX 1

Dust Suppressant Information Sheets

This Appendix is comprised of dust suppressant information sheets. The following products have been used for dust suppression in northern and western Canada and are detailed in individual information sheets:

Note: Standard equipment: Refers to usual equipment used for surface course preparation, such as grader, and for suppressant application, such as a spray-bar type water truck.

Compaction equipment, for compacting the final surface after suppressant application, may also be desired and is generally recommended.

Standard Preparation: Refers to the preparation of the surface course which involves grading to remove imperfections, recover fines from berms, and establish good crown. Tight blading of final surface is generally recommended as this usually increases suppressant performance and longevity.

APPENDIX 1

Dust Suppressant Information Sheet Index

WATER AND WETTING AGENTS

Alchem 8808

DELIQUESCENT AND HYGROSOPIC CHEMICALS

Calcium Chloride
Sodium Chloride
Salt Brines

ORGANIC NON-BITUMINOUS BINDERS

Modified Calcium Lignosulfonate
Sodium Lignosulfonate
Ammonium and Sodium Lignosulfonate
Read Chemicals Lignosulfonate
Spent Sulfite Luquor
DC-M18

PETROLEUM BASED SUPPRESSANTS

Used Oil, Waste Oil
Bunker Oil
DL-10
Emulsified Asphalt Primer
Coherex
Slow Curing Liquid Ashpalt, SC30
Liquid Asphalt, MC30
Emulsified Asphalt SS1
Asphalt Road Primer
Decant Oil
Re-refined Oil
Heavy Crude Oil

Dust Suppressant Information Sheet

Category: Water and Wetting Agents

Name: Alchem 8808

Manufacturer/Distributor:
- o Alchem Inc. Burlington, Ontario.
- o Shipped in bulk quantities or in steel drums containing approximately 190 kg net wt.

Application/Effectiveness:
- o Not recommended for long-term public road dust suppression.
- o Suitable for mine haul road dust suppression.
- o Not easily leached from roadbed.

Cost breakdowns: Not determined.

General Application Procedures:
- o Added at 2 to 3% concentration directly to the amount of water that would usually be applied.
- o Once a base is built up, the frequency of application and solution concentration is reduced to maintain the desired level of control. (Generally requiring only a 0.5% solution every 2 to 3 days).
- o Alchem Representative will recommend the proper dust control program for each situation.

Men & Equipment (Storage) Requirements:
- o Standard Equipment.
- o Recommended maximum in-plant storage of drums is 12 months.

Preparation of Suppressant:
1. Fill tank one-half full with water.
2. Add desired amount of Alchem 8808 to tank.
3. With water hose under the liquid surface, fill the tank.

Preparation of Road Bed: As for normal watering.

Precautions/Problems:
- o If water is allowed to casade when mixing a foaming problem may occur.
- o Inhalation of mist, eye contact, ingestion, or prolonged or repeated contact with skin should be avoided.
- o Keep container closed and away from heat or open flame.
- o Recommended maximum in-plant storage of unopened drums is 12 months.

Components: Aliphatic hydrocarbons in combination with wetting agents and binders.

Properties:
- Maintains good flow properties at temperatures above -10°C.
- Freeze-thaw recovery Complete.
- Cloud point - 7°C
- Pour point -16°C
- Viscosity @25°C (No. 1 @ 30 rpm) 52 mPas
- Relative Density @ 25°C 0.91
- Flash Point (TCC) > 100°C

Toxicity: Contains aliphatic hydrocarbons and surfactants that may be potentially toxic.

Environmental Considerations:
- o Precautions for human contact suggest that some environmental implications may exist.
- o Apparently induces none of the environmental problems often associated with waste oil use.

Social Considerations: None apparent.

References:
Alchem Inc. 1982
Alchem Commercial Product Brochures

Dust Suppressant Information Sheet

Category: Deliquescent and Hydroscopic Chemicals

Name: Calcium Chloride ($CaCl_2$)

Manufacturer/Distributor:
- o Allied Chemical,
- o Dow Chemical,
- o Harrisons and Crossfield,
- o Canadian Industries Limited (C.I.L.) Inc.

Application/Effectiveness:
- o Generally 2 applications per dust suppression season.
- o May require occasional watering in dry periods.
- o Generally excellent effectiveness in drier climates; however, less effective than lignosulfonates when very dry.
- o Cannot be relied upon to carry over to next dust season.
- o Optimum road surface gradation 10-15% fines

Cost breakdowns: $185 to $310 per Tonne Flake Equivalent, F.O.B. delivered and applied in western Canada.

General Application Procedures:
- o Ranges from 2 to 8 tonnes of solid $CaCl_2$ per kilometre, (2 lane road).
- o Ranges from 0.5 to 5.0 litres per square metre for liquid $CaCl_2$.
- o Most commonly 2.2 litres of liquid per square metre or 6 tonnes of solid per kilometre (2 lane road).
- o Second application generally one-half of the first.

Men & Equipment (Storage) Requirements:
- o Manufacturers will supply applications.
- o Allied only sells liquid with application included.
- o Grader needed for roadbed preparation.

Preparation of Suppressant: None, unless making liquid from flake is desired.

Preparation of Road Bed:
- o Ranges from scarifying and applying suppressant between 2 to 3 passes of the grader to simple pass of grader and top application.
- o Most commonly road is graded and suppressant applied.
- o Compaction of final surface is recommended.

Precautions/Problems:
- o Poor quality soils take longer to recover from wetting.
- o Progressively leached from road by rainfalls causing suppression loss and roadbed deterioration.
- o Complaints from taxpayers on excess rusting of vehicles have been reported.
- o Fresh calcium chloride causes drying and cracking of leather, workers should wear rubber boots.
- o Surface "crust" which is created by $CaCl_2$ may be slippery in wet weather.

Components: Calcium Chloride and Water, Solid flake is 70-80% $CaCl_2$
Liquid is 30-42% $CaCl_2$
Commercial Natural Brines are 20-25% $CaCl_2$

Properties:
- o Deliquescent - will absorb water directly from the air.
- o Hygroscopic - absorbs large amounts of water.
- o Lower vapour pressure than water - takes much longer for road to lose moisture.
- o Exothermic - generates heat when dissolving - a good road de-icer.

Toxicity:
- o Midly toxic to some plants such as fruit trees.

Dust Suppressant Information Sheet

Category: Deliquescent and Hydroscopic Chemicals

Name: Calcium Chloride ($CaCl_2$) (Continued)

Environmental Considerations:
- o No build-up of components has been measured in the field.
- o Mildly toxic to some plants such as fruit trees.

Social Considerations:
- o May cause hardening of local water.
- o Use near fruit tree orchards may warrant initial testing due to potential toxicity.
- o Road surface may be slippery when wet.
- o May cause corrosion of vehicles.

References:

Allied Chemical 1982
Allied Chemical Commercial Product Brochures
B.C. Dept. of Highways 1980-1981
Boyd and Van Cauwenberghe 1980
Canadian Industries Limited 1982
Dow Chemical Commercial Product Brochures
Dow Chemical 1982
Harrisons and Crossfield 1982
Mason et al. 1981
Mulholland 1972

Dust Suppressant Information Sheet

Category: Deliquescent and Hygroscopic Chemicals

Name: Sodium Chloride (NaCl)

Manufacturer/Distributor:

Application/Effectiveness:
- o Not recommended for dust suppression because it requires a high relative humidity (70 to 80%) to be effective.
- o Has been used successfully with calcium chloride but results not as efficient as straight calcium chloride and takes more time to apply both.

Cost Breakdowns: Not determined.

General Application Procedures:
- o Applied the same as bulk flake calcium chloride.
- o Straight sodium chloride may be applied in heavier applications although this does not improve performance in extended dry periods.

Men & Equipment (Storage) Requirements:
- o Same as for solid calcium chloride.
- o More time required when both are applied since the sodium chloride should be dissolved into the wetted road surface before calcium chloride is applied.

Preparation of Suppressant:
- o None required.
- o Dissolving sodium chloride for liquid application is generally not feasible due to resulting weak solutions.

Preparation of Road Bed:
- o Standard Preparation.
- o Often watered to aid in dissolving the sodium chloride upon application.

Precautions/Problems:
- o Progressively leached from road by rainfall.
- o Not considered an effective dust suppressant. Benefits from mixing with calcium chloride do not appear greater than for using straight calcium chloride.

Components: Sodium Chloride (Rock Salt)

Properties: Deliquescent - will absorb water directly from the air if relative humidity is sufficient.

Toxicity: o Mildly toxic to some plants such as fruit trees.

Environmental Considerations:
- o No build up has been measured in the field for calcium chloride, similar results expected with sodium chloride.
- o Mildly toxic to some plants such as fruit trees.
- o May cause corrosion of vehicles

Social Considerations:
- o May cause hardening of local water.
- o Not recommended for dust suppression, generally does not represent best dollar value for taxpayers.

Reference: Mulholland 1972

Dust Suppressant Information Sheet

Category: Deliquescent and Hygroscopic Chemicals

Name: Salt Brines

Manufacturer/Distributor: Local Contractors

Application/Effectiveness:

- If contain greater than 7% calcium chloride may be considered cheaper than commercially available calcium chloride.
- Some commercially available calcium chloride comes from brine sources in Alberta.
- May not be effective in very dry conditions.
- Low content brines (ie 7 to 15% $CaCl_2$) are generally not recommended for heavily travelled roads but are considered very good for low traffic volume roads where maintenance and service demands are not high.
- It may not be possible to concentrate low content brines much further by successive passes due to the relatively large quantities of water involved.

Cost Breakdowns: Not determined, may be cheaper than commercial calcium chloride products.

General Application Procedures:

- Applied the same as liquid Calcium chloride although more passes are necessary to achieve the same road surface concentration, if desired.
- May not be possible to achieve significant road surface concentrations.

Men & Equipment (Storage) Requirements:

- Same as for liquid calcium chloride.
- More time may be required per site for extra passes if similar road surface concentrations as for commercial calcium chloride are desired and possible.

Preparation of Suppressant:

- None required.
- If desired it may be possible to evaporate off some of the water in storage lagoons to achieve a more concentrated solution, more similar to brines commercially available as liquid calcium chloride (20 and 25% solutions).

Preparation of Road Bed:

- Standard Preparation.

Precautions/Problems:

- May not be possible to achieve greater road surface concentrations of calcium chloride by increasing the number of passes.
- May only be suitable for low traffic volume roads.
- Use on heavier travelled roads may require more frequent applications.
- Progressively leached from road by rainfalls causing suppression and road surface deterioration.

Components:

- Calcium Chloride
- Water
- Often contains other salts

Properties: Deliquescent - will absorb water directly from the air.

Dust Suppressant Information Sheet

Category: Deliquescent and Hygroscopic Chemicals

Name: Salt Brines (Continued)

Toxicity: o Mildly toxic to some plants such as fruit trees.

Environmental Considerations:
- o No build up has been measured in the field for calcium chloride.
- o Mildly toxic to some plants such as fruit trees.
- o May cause corrosion of vehicles.

Social Considerations:
- o May cause hardening of local water
- o Use near fruit tree orchards may warrant initial testing due to potential toxicity.
- o Road surface may be slippery when wet.

Reference: Ontario Ministry of Transportation 1982

Dust Suppressant Information Sheet

Category: Organic Non-Bituminous Binder

Name: Modified Calcium Lignosulfonate
- M & F Stabliser
- Lignosite

Manufacturer/Distributor:
- Georgia Pacific, Bellingham, Washington
- MacKenzie & Feimann, Vancouver, B.C.
- Van Waters and Rogers Ltd., Vancouver, B.C.

Application/Effectiveness:
- o Generally 2 applications, of 2 litres per square metre, per dust suppression season.
- o Most successful form of lignosulfonate to date in the northern and western Canada.
- o Superior to calcium chloride in long periods of dry weather.
- o Heavy rain can lead to product leaching but apparently less than for calcium chloride.

Cost breakdowns:
- o F.O.B. supplied and applied as 1:1 dilution about $.22 to $.33 per litre of concentrate.
- o F.O.B. study area $.15 to $.33 per litre of concentrate.

General Application Procedures: Generally 1.9 - 2.2 litres per square metre applied in 1 or 2 passes.

Men & Equipment (Storage) Requirements:
- o Standard Equipment.
- o Specialized storage equipment not required.
- o Traffic control may be desired as product cures.

Preparation of Suppressant: Always a 1:1 dilution with water.

Preparation of Road Bed:
- o Tightly blade, shoving excess over side slope to be retrieved if surface becomes slippery in rain.
- o Compact after product application.
- o Final surface should be firm and smooth with a good cross section.

Precautions/Problems:
- o Suppressant preparation and application instructions must be strictly followed.
- o Road surface may become slippery when wet.
- o Rapid drying of application should be avoided.
- o Requires a minimum of road surface fines similar to calcuim chloride.
- o May foam severly if water allowed to cascade in mixing.

Components: Modified lignosulfonates from sulfite pulping process with a calcium base, other wood and pulping residue.

Properties:

- Color:	Dark brown
- Smell:	Strong odor
- Sp. Gravity	1.255
- pH:	6.0
- Solids:	50.57%

Toxicity:
- o Essentially non-toxic: generally very low toxicity.
- o Moderately toxic to rainbow trout.

Environmental Considerations:
- o Biodegradation slow - persistent in the environment.
- o Moderately toxic to rainbow trout.
- o Calcium lignosulfonate was found to be more benign to the soil, than sodium based, in a B.C. Dept. of Highways study.

Social Considerations:
- o Molasses-like smell not considered offensive.
- o Road surface may become slippery when wet.

Dust Suppressant Information Sheet

Category: Organic Non-Bituminous Binder

Name: Modified Calcium Lignosulfonate (Continued)
- M & P Stabiliser
- Lignosite

References:
B.C. Dept. of Highways 1980-1981
Boyd and Van Cauwenberghe 1980
Mackenzie and Feimann 1982
Mackenzie and Feimann Commercial Product Brochures
Mason et al. 1982
Mullholland 1972
Sontowski and Vliet 1977
VanWaters and Rogers 1982

Dust Suppressant Information Sheet

Category: Organic Non-Bituminous Binder

Name: Sodium Lignosulfonate, Raylig (Rayobinder)

Manufacturer/Distributor: ITT Rayonier
Shelton, Washington
Was distributed by Harrisons and Crossfield, Vancouver B.C.

Application/Effectiveness:
- Generally no widespread use of this product in northern and western Canada.
- Studies by the B.C. Dept. of Highways indicated that modified calcium lignosulfonate is the most successful form available to date in northern and western Canada; however, all lignosulfonates available provide satisfactory dust suppression.
- Generally 2 applications, of 2 litres per square metre, per dust suppression season.
- Most likely superior to calcium chloride in long periods of dry weather.
- Heavy rain can lead to product leaching but most likely less than from calcium chloride.

Cost breakdowns: Not determined.

General Application Procedures: Generally 1.9 - 2.2 litres per square metre applied in 1 or 2 passes.

Men & Equipment (Storage) Requirements:
- Standard Equipment.
- Specialized storage equipment not required.
- Traffic control may be desired as product cures.

Preparation of Suppressant: Generally a 1:1 dilution with water is most successful.

Preparation of Road Bed:
- Tightly blade, shoving excess over side slope to be retrieved if surface becomes slippery in rain.
- Compact after product application.
- Final surface should be firm and smooth with a good cross section.

Precautions/Problems:
- Suppressant preparation and application instructions must be strictly followed.
- Road surface may become slippery when wet.
- Rapid drying of application should be avoided.
- Requires a minimum of road surface fines similar to calcuim chloride.
- May foam severly if water allowed to cascade in mixing.

Components: Lignosulfonates from sulfite pulping process with a sodium base, other wood and pulping residue.

Properties:

- Color:	Dark brown
- Smell:	Strong molasses-like odor
- Sp. Gravity	1.264 - 1.282
- pH:	5.35 - 5.6
- Solids:	53.5 - 54.5%

Toxicity:
- Essentially non-toxic: generally very low toxicity.
- Moderately toxic to rainbow trout.

Environmental Considerations:
- Biodegradation slow - persistent in the environment.
- Moderately toxic to rainbow trout.
- Sodium based lignosulfonates may change local soil properties if contamination of local soils occurs.

Dust Suppressant Information Sheet

Category: Organic Non-Bituminous Binder

Name: Sodium Lignosulfonate, Raylig (Rayobinder) (Continued)

Social Considerations:
- o Molasses - like smell not considered offensive.
- o Road surface may become slippery when wet.

References:
Mason et al. 1981
Sontowski and Vliet 1977

Dust Suppressant Information Sheet

Category: Organic Non-Bituminous Binder

Name: Ammonium and Sodium Lignosulfonate, Orzan GL-50

Manufacturer/Distributor:
- Crown Zellerbach
  Seattle, Washington
  Was distributed by Van Waters and Rogers, Vancouver B.C., who now distribute Modified Calcium Lignosulfonate

Application/Effectiveness:
- o Used for dust suppression in the Lignosulfonate as MacKenzie and Peiman.
- o Generally no widespread use of this product in norther and western Canada.
- o Studies by the B.C. Dept. of Highways indicated that modified calcium lignosulfonate is the most successful form available to date in norhtern and western Canada; however, all lignosulfonates available provide satisfactory dust suppression.
- o Generally 2 applications, of 2 litres per square metre, per dust suppression season.
- o Most likely superior to calcium chloride in long periods of dry weather.
- o Heavy rain can lead to product leaching but most likely less than from calcium chloride.

Cost breakdowns: Not determined.

General Application Procedures: Generally 1.9-2.2 litres per square metre applied in 1 or 2 passes.

Men & Equipment (Storage) Requirements:
- o Standard Equipment.
- o Specialized storage equipment not required.
- o Traffic control may be desired as produce cures.

Preparation of Suppressant:
- o Generally a 1:1 dilution with water is most successful.
- o Dilutions up to 1:3 and as low as 2.25:1 have been used in the U.S.

Preparation of Road Bed:
- o Tightly blade, shoving excess over side slope to be retrieved if surface becomes slippery in rain.
- o Compact after product application.
- o Final surface should be firm and smooth with a good cross section.

Precautions/Problems:
- o Suppressant preparation and application instructions must be strictly followed.
- o Road surface may become slippery when wet.
- o Rapid drying of application should be avoided
- o Requires a minimum of road surface fines similar to calcuim chloride.
- o May foam severly if water allowed to cascade in mixing.

Components: Lignosulfonates from sulfite pulping process with an ammonium and sodium base, other wood and pulping residue.

Properties:
- Color: Dark brown
- Smell: Strong molasses-like odor
- Sp. Gravity 1.286
- pH: 4.1
- Solids: 55.7%

Toxicity:
- o Essentially non-toxic: generally very low toxicity.
- o Moderately toxic to rainbow trout.

Dust Suppressant Information Sheet

Category: Organic Non-Bituminous Binder

Name: Ammonium and Sodium Lignosulfonate, Orzan GL-50 (Continued)

Environmental Considerations:

- Biodegradation slow - persistent in the environment.
- Moderately toxic to rainbow trout. Sodium based lignosulfonates may change local soil properties if contamination of local soils occurs.

Social Considerations:

- Molasses-like smell not considered offensive.
- Road surface may become slippery when wet.

References:

Hoover 1981
Mason et al. 1981
Sontowski and Vliet 1977
Sultan 1976

Dust Suppressant Information Sheet

Category: Organic Non-Bituminous Binder

Name: Read Chemicals Lignosulfonate

Manufacturer/Distributor: Canadian Industries Limited (C.I.L.), Inc.
Edmonton, Alberta

Application/Effectiveness:
- Currently not used for dust suppression in northern and western Canada.
- A solid form of lignosulfonate that appears competitive in northern and western Canada if direct application is in solid form.
- Solid lignosulfonates have been used for dust suppression and subgrade stablization in the U.S.
- May be less likely leached in rain than liquid lignosulfonates.
- May be superior to calcium chloride in long day periods.

Cost breakdowns:
- About $.21 per kilogram F.O.B. Calgary.

General Application Procedures: Generally mixed into windrow to attain 1 to 2% lignosulfonate in the surface course.

Men & Equipment (Storage) Requirements:
- Grader for road bed preparation and mixing.
- Spray bar type truck may only be required if watering is desired.
- Specialized storage equipment not required.

Preparation of Suppressant: None.

Preparation of Road Bed:
- Grade and windrow, removing imperfections and maintaining crown.
- Mix desired amount of solid lignosulfonate in windrows and grade.
- Water and compact.
- Final surface should be firm and smooth with a good cross section.

Precautions/Problems:
- Road surface may become slippery when wet.
- May require a minimum of road surface fines similar to calcuim chloride.

Components: Lignosulfonates from sulfite pulping process with an unknown base, other wood and pulping residue.

Properties: A solid lignosulfonate.

Toxicity:
- Essentially non-toxic: generally very low toxicity.
- Moderately toxic to rainbow trout.

Environmental Considerations:
- Biodegradation slow - persistent in the environment.
- Moderately toxic to rainbow trout.
- If sodium based, may change local soil properties if contamination of local soils occurs.

Social Considerations:
- Molasses-like smell not considered offensive.
- Road surface may become slippery when wet.

References:
Canadian Industries Limited 1982
Sultan 1976

Dust Suppressant Information Sheet

Category: Organic Non-Bituminous Binder

Name: Spent Sulfite Liquor, Spent Pulping Liquor, Lignin Sulfonate, Black Liquor.

Manufacturer/Distributor:
- Rayonier pulp-mill, Port Alice, B.C.
- Domtar pulp-mill near Trenton, Ontario

Application/Effectiveness:
- Ammonium based very effective in Port Alice area, regardless of very high rainfall (292 cm yearly average).
- Heavy rain does not appear to lead to significant leaching.
- Used very successfully near Trenton, Ontario.
- Mostlikely superior to calcium chloride in long periods of dry weather.

Cost breakdowns:
- Not determined.
- Was available free to local townships in both locations.
- No longer available at Port Alice as Rayonier uses excess itself and burns the rest as hog fuel.
- No longer applied at Trenton due to PCB contamination.

General Application Procedures: Most likely 1.9-2.2 litres per square metre applied in 1 or 2 passes.

Men & Equipment (Storage) Requirements:
- Standard Equipment.
- Specialized storage equipment not required.
- Trafic control may be desired as product cures.

Preparation of Suppressant: May be diluted 1:1 with water.

Preparation of Road Bed:
- Tightly blade, shoving excess over side slope to be retrieved if surface becomes slippery in rain.
- Compact after product application.
- Final surface should be firm and smooth with a good cross section.

Precautions/Problems:
- Suppressant preparation and application instructions must be strictly followed.
- Road surface may become slippery when wet.
- Rapid drying of application should be avoided.
- Requires a minimum of road surface fines similar to calcuim chloride.
- May foam severly if water allowed to cascade in mixing.

Components: Lignosulfonates from sulfite pulping process with a variable base, other wood and pulping residue.

Properties:
- Color is dark brown.
- Non hygroscopic.
- Strong molasses-like odor.
- Forms colloidal solutions or dispersions in water.
- Practically insoluble in all organic soluents.

Toxicity:
- Essentially non-toxic: generally very low toxicity.
- Moderately toxic to rainbow trout.

Environmental Considerations:
- Biodegradation slow - persistent in the environment.
- Moderately toxic to rainbow trout.
- If sodium based, may change local soil properties if contamination of local soils occurs.
- May contain toxic substances from pulping process.

Social Considerations:
- Molasses-like smell not considered offensive.

References:
Mason et al. 1981
Ontario Ministry of Transportation 1982

Dust Suppressant Information Sheet

Category: Organic Non-Bituminous Binder

Name: DC-M18

Manufacturer/Distributor: United International Industries Ltd. (U.I.I.L.), Calgary, Alberta

Application/Effectiveness:
- A new product that was first tested in 1981 with encouraging results - available commercially.
- U.I.I.L. is continuing experimenting and testing under various conditions to determine effectiveness and applications for potential users.
- Apparently good for excessive fines.
- Generally 2 to 3 applications per year totalling 280 to 340 liters of suppressant per kilometer.
- Does not provide total dust control but provides safe visibility for an extended length of time.

Cost breakdowns:
- $2 to $3 per litre depending on order size.

General Application Procedures:
- Generally applied with water at a rate of 140 to 170 litres of suppressant per km in two passes (9m road) which equals one litre of suppressant per 22 to 55 m^2.
- Object is to achieve 2.0 cm penetration, check to ensure that this is in fact occurring and adjust application rate as necessary.

Men & Equipment (Storage) Requirements: Standard Equipment.

Preparation of Suppressant: Presently 140 to 170 litres of DC-M18 is mixed with 22,730 litres of water for application to a 9 m road in 2 passes.

Preparation of Road Bed: Tight blade the surface - removing loose material, potholes, and washboard.

Precautions/Problems:
- This is a new product with successful results, however, testing for local condition applicability encouraged before larger scale endorsement.
- Always add DC-M18 to the water to avoid excessive foaming.

Components: An enzyme-based biochemical in solution with a very heavy organic polymer and a wetting agent.

Properties:
- Clear, yellowish liquid that appears soapy and slightly heavier than water.
- Promotes particle to particle adhesion and weighs the dust down to provide safe visibility.

Toxicity: Initial test indicate DC-M18 is non-toxic and non-acidic.

Environmental Considerations: Manufacturer says product is completely biodegradable and none of the ingredients are toxic.

Social Considerations: No strong odor.

References:
United International Industries Limited (U.I.I.L.) 1982
U.I.I.L. Commercial Product Brochures

Dust Suppressant Information Sheet

Category: Petroleum Based Suppressant

Name: Used oil, Waste Oil

Manufacturer/Distributor:

Application/Effectiveness:
- o Very effective as a dust suppressant-generally more effective than calcium chloride or lignosulfonates and longer lasting.
- o However, leached by rain leading to eventual deterioration of performance.
- o Generally 2 applications the first year and 1 or 2 each year thereafter.

Cost breakdowns: Approximately $.02 to $.10/litre.

General Application Procedures:
- o Generally applied at 1.1 to 1.7 litres per square meter either directly to prepared surface or mixed into windrows.
- o Heavy applications may be as high as 2.7 litres per square meter.

Men & Equipment (Storage) Requirements:
- o Standard Equipment.
- o No specialized storage requirements.

Preparation of Suppressant:
- o Generally none, applied as collected from sources such as gas stations.
- o Possibly distilled by contractor.

Preparation of Road Bed:
- o Standard preparation.
- o May be mixed into windrows during road preparation.

Precautions/Problems:
- o Used oil imposes a considerable environmental threat because of heavy metals (especially lead), P.N.A.'s and P.C.B.'s which it may contain.
- o Should not be used where surface runoff enters nearby water course or body, or in high water table areas.
- o Use of used oil containing significant amounts of used transformer oil is strongly discouraged due to P.C.B. contamination potential.
- o Under certain conditions, such as a wet spring, it may be necessary to supplement the first application with a second or third later in the season.
- o May be prone to potholing in very wet weather.
- o Roads with high clay content need greater applications.

Components:
- o Used lubricating oils-usually crankcase oil from automobiles.
  - Water 4.4% on average.
  - Lead 1.1% on average - expected to be declining with increased use of unleaded gasolines.

Properties:
- Sp. Gravity: 24.6 API on average.
- Viscosity: at 37.8°C, 53.3 centistokes on average.
- Flash pt.: 102°C on average.

Toxicity: Common contaminants potentially very toxic and carcinogenic.

Environmental Considerations:
- o Used oil imposes a considerable environmental threat because of heavy metals (especially lead), P.N.A.'s, and P.C.B.'s which it may contain.
- o Use discouraged in northern and western Canada.

Dust Suppressant Information Sheet

Category: Petroleum Based Suppressant

Name: Used oil, Waste Oil (Continued)

Social Considerations:

- Use of used oil for dust suppression has been discouraged at the provincial level in western Canada in favor of energy conservation and environmental protection.
- Smell or appearance may be less desirable than other dust suppression alternatives such as calcium chloride or lignosulfonates.

References:
Interministerial Committee on Waste Oil Recycling 1981
Love and Associates 1979
Mason et al. 1981
Skinner 1974
Waste Management Advisory Board 1978

Dust Suppressant Information Sheet

Category: Petroleum Based Suppressant

Name: Bunker Oil, Road Oil, Medium Curing Oil (M.C.O., M.C.2)

Manufacturer/Distributor:

Application/Effectiveness:
- o Very effective as a dust suppressant - generally more effective than calcium chloride or lignosulfonate and longer lasting.
- o Generally costlier than other alternatives such as calcium chloride or lignosulfonates.
- o Commonly develops potholing problems.
- o May cure hard, making road surface difficult to rework.

Cost breakdowns:
- o Considerably more expensive than used oil.
- o Generally more expensive than other dust suppression alternatives such as calcium chloride or lignosulfonates.

General Application Procedures: Generally applied at 1.1 to 1.35 litres per square metre.

Men & Equipment (Storage) Requirements:
- o Standard Equipment.
- o No specialized storage requirements.

Preparation of Suppressant: Usually applied as supplied.

Preparation of Road Bed: Standard Preparation.

Precautions/Problems:
- o Use of petroleum products for dust suppression is generally discouraged at the provincial level in western Canada in favor of energy conservation.
- o Roads with high clay content need greater applications.
- o Prone to potholing in very wet weather.

Components:
- o Bunker "A" least asphalt.
- o Bunker "B" less asphalt.
- o Bunker "C" 7 to 25% asphalt.

Properties:
- o Bunker "A" lightest of the 3.
- o Bunker "B" slightly lighter than "C".
- o Bunker "C" heaviest viscosity oil that refineries produce.
- o Moderate fire hazard when exposed to heat or flame.

Toxicity: Contains hydrocarbons that may be potentially toxic.

Environmental Considerations:
- o Potential hydrocarbon contamination of nearby water courses, bodies, or ground water.
- o Full environmental implications of use not well researched.

Social Considerations:
- o Use of petroleum products for dust suppression is generally discouraged at the provincial level in western Canada in favor of energy conservation.
- o Smell or appearance may be less desirable than other dust suppression alternatives such as calcium chloride or lignosulfonates.

References:
Mason et al. 1981
Saskatchewan Dept. of Highways, n.d.

Dust Suppressant Information Sheet

Category: Petroleum Based Suppressant

Name: DL-10 Asphalt Emulsion

Manufacturer/Distributor: Pounder Emulsions
Winnipeg, Manitobia

Application/Effectiveness:
- o Does not harden, remaining workable for standard grader maintenance.
- o Not leached in rain like calcium chloride or lignosulfonates.
- o Generally 3 applications for the first year then 2 each year thereafter.

Cost breakdowns: $.16 to $.20 per litre.

General Application Procedures: Generally applied in one pass at a rate of 1.8 litres per square metre.

Men & Equipment (Storage) Requirements:
- o Standard Equipment.
- o Traffic control may be desired as product cures.

Preparation of Suppressant:
- o None, applied as supplied.
- o If large quantity ordered, may be supplied in more concentrated form which would have to be diluted with warm water (22°C) which was not too hard (low in calcium levels).

Preparation of Road Bed:
- o Standard Preparation.
- o Small windrow may be left to serve as blotter during application and smoothed out after to ensure positive roadbed drainage.

Precautions/Problems:
- o Traffic control may be desired as product cures.
- o If concentrated form used, dilution water must not be too hard.

Components: Asphalt and other petroleum products.

Properties:
- o Reworkable.
- o Moderate fire hazard when exposed to heat or flame.

Toxicity: Contains hydrocarbons that may be potentially toxic.

Environmental Considerations:
- o Product generally remains in the roadbed.
- o Potential hydrocarbon contamination of local water bodies, particularly if applied excessively.

Social Considerations: Strength of odor unknown.

References:
Mulholland 1972
Pounder Emulsions 1982

Dust Suppressant Information Sheet

Category: Petroleum Based Suppressant

Name: Emulsified Asphalt Primer, EAP

Manufacturer/Distributor: Pounder Emulsions
Winnipeg, Manitobia

Application/Effectiveness:
- o Successfully used on sandy soils in northwest Ontario.
- o Cures harder than DL-10 making it less desirable for finer roadbed due to probable pothole problem.
- o Generally only one application per year.

Cost breakdowns: $.16 to $.20 per litre.

General Application Procedures: Generally applied in one pass at a rate of 1.8 litres per square metre.

Men & Equipment (Storage) Requirements:
- o Standard Equipment.
- o Traffic control may be desired as product cures.

Preparation of Suppressant: None, applied as supplied.

Preparation of Road Bed:
- o Standard Preparation.
- o Small windrow may be left to serve as blotter during application and smoothed out after to ensure positive roadbed drainage.

Precautions/Problems:
- o Hardened crust makes road surface more difficult to rework and promotes potholing in most surface courses.
- o Traffic control may be desired as product cures.

Components: Asphalt emulsified in "locked-in" solvents.

Properties:
- o Difficult to rework.
- o Moderate fire hazard when exposed to heat or flame.

Toxicity: Contains hydrocarbons that may be potentially toxic.

Environmental Considerations:
- o Product generally remains in the roadbed.
- o Potential hydrocarbon contamination of local water bodies, particularily if applied excessively.

Social Considerations: Strength of odor unknown.

Reference: Pounder Emulsions 1982

Dust Suppressant Information Sheet

Category: Petroleum Based Suppressant

Name: Coherex

Manufacturer/Distributor: Witco Chemical
Calgary, Alberta

Application/Effectiveness:
- Available reports reveal differing results with use, varying from bad to good.
- Witco notes that Coherex is a suitable alternative to calcium chloride in very dry conditions.
- Variable application rate to suit local conditions.

Cost breakdowns: $.33 to $.66 per liter F.O.B job site

General Application Procedures: Generally a 1:4 dilution with water applied in 2 passes of 2 to 3 litres per square metre.

Men & Equipment (Storage) Requirements:
- Standard Equipment.
- A glyceride should be added to Coherex to make it freeze-thaw stable and prevent coagulation of resins in storage.

Preparation of Suppressant: Dilute with water (dilutions range from 1:4 to 1:7 - most commonly 1:4).

Preparation of Road Bed:
- Witco recommends scarification to 15 cm followed by successive applications with windrow mixing followed by compaction of the final surface.
- Some users employ Standard Preparation procedures.

Precautions/Problems:
- Testing of product recommeded before large scale use.
- Creates handling problems if coagulates due to improper storage.
- Skinning has been reported in surface applications which may make road surface reworking impractical.

Components: Concentrated emulsion of petroleum oils and resins.
- about 60% resins (residue) and 40% wetting solution.

Properties:

- Viscosity SUS @ 37.8°C, seconds	6000 min.
- Flash point, COC	204°C min.
- Sp. Gravity	1.02
- pH: @ 26°C	7.1

Toxicity: Witco states Coherex is practically non-toxic and not considered an eye irritant or primary skin irritant.

Environmental Considerations:
- Apparently non-injurious to plant growth.
- Coherex in storm water run-off results in virtually no oxygen decrease in waterways.
- Some impacts have been noted in the U.S., details unavailable at time of printing.

Social Considerations:
- Virtually no odor added to road surface.
- Yellow colour only while product cures.

References:
B.C. Dept. of Highways 1981
B.C. Dept. of Highways 1980-1981
Witco Chemicals 1982
Witco Chemicals Commercial product Brochures

Dust Suppressant Information Sheet

Category: Petroleum Based Suppressant

Name: Slow Curing Liquid Asphalt, SC30

Manufacturer/Distributor:

Application/Effectiveness:
- o Effective as a dust suppressant although surface may pothole.
- o Generally 2 applications the first year followed by 1 or 2 applications per year thereafter.
- o Generally can be rebladed fairly successfully.
- o May cure hard making it less desirable due to potential pothole problem and by it becoming difficult to rework.
- o Generally only one application per year.

Cost breakdowns: Not determined.

General Application Procedures:
- o Generally applied in one pass at a rate of 1.35 to 1.65 litres per square metre.

Men & Equipment (Storage) Requirements:
- o Standard Equipment.
- o Traffic control may be desired as product cures.

Preparation of Suppressant: None, applied as supplied.

Preparation of Road Bed:
- o Standard Preparation.
- o Small windrow may be left to serve as blotter during application and smoothed out after to ensure positive roadbed drainage.
- o May be mixed into windrow and laid over surface.

Precautions/Problems:
- o If hardened, crust may make road surface more difficult to rework and promotes potholing.
- o Traffic control may be desired as product cures.

Components: Asphalt and solvents.

Properties:
- o Difficult to rework, but not as difficult as harder curing asphalt products.
- o Moderate fire hazard when exposed to heat or flame.

Toxicity: Contains hydrocarbons that may be potentially toxic.

Environmental Considerations:
- o Product generally remains in the roadbed.
- o Potential hydrocarbon contamination of local water bodies, particularily if applied excessively.

Social Considerations: Strength of odor unknown.

Reference: Saskatchewan Department of Highways n.d.

Dust Suppressant Information Sheet

Category: Petroleum Based Suppressant

Name: Liquid Asphalt, MC30 (medium curing)

Manufacturer/Distributor:

Application/Effectiveness:
- o Effective as a dust suppressant, however generally not recommended.
- o Surface will usually pothole eventually, deteriorating ridability.
- o Cures hard making it less desirable due to potential pothole problem and by it becoming difficult to rework.
- o Generally only one application per year.

Cost breakdowns: Not determined.

General Application Procedures:
- o Generally applied in one pass at a rate of 1.1-1.4 litres per square metre.

Men & Equipment (Storage) Requirements:
- o Standard Equipment.
- o Traffic control may be desired as product cures.

Preparation of Suppressant: None, applied as supplied.

Preparation of Road Bed:
- o Standard Preparation.
- o Small windrow may be left to serve as blotter during application and smoothed out after to ensure positive roadbed drainage.
- o May be mixed into windrow and laid over surface.

Precautions/Problems:
- o Hardened crust makes road surface more difficult to rework and promotes potholing.
- o Traffic control may be desired as product cures.

Components: Asphalt and solvents.

Properties:
- o Difficult to rework.
- o Moderate fire hazard when exposed to heat or flame.

Toxicity:
- o Contains hydrocarbons that may be potentially toxic.

Environmental Considerations:
- o Product generally remains in the roadbed.
- o Potential hydrocarbon contamination of local water bodies, particularily if applied excessively.

Social Considerations: Strength of odor unknown.

Reference: Saskatchewan Dept. of Highways n.d.

Dust Suppressant Information Sheet

Category: Petroleum Based Suppressant

Name: Emulsified Asphalt, SS1

Manufacturer/Distributor:

Application/Effectiveness:
- Effective as a dust suppressant, however generally not recommended.
- Surface will usually pothole eventually, deteriorating ridability.
- Cures hard making it less desirable due to potential pothole problem and by it becoming difficult to rework.
- Generally only one application per year.

Cost breakdowns: Not determined.

General Application Procedures:
- Generally put down in 2 or more passes with increasingly stronger solutions to concentrate the asphalt in the surface.
- Total application generally 1.1 to 1.4 litres per square metre.

Men & Equipment (Storage) Requirements:
- Standard Equipment.
- Traffic control may be desired as product cures.

Preparation of Suppressant: Needs to be applied in a very dilute form to get good penetration or to mix well.

Preparation of Road Bed:
- Standard Preparation.
- Small windrow may be left to serve as blotter during application and smoothed out after to ensure positive roadbed drainage.
- May be mixed into windrow and laid over surface.

Precautions/Problems:
- Hardened crust makes road surface more difficult to rework and promotes potholing.
- Traffic control may be desired as product cures.

Components: Asphalt and solvents.

Properties:
- Difficult to rework.
- Moderate fire hazard when exposed to heat or flame.

Toxicity: Contains hydrocarbons that may be potentially toxic.

Environmental Considerations:
- Product generally remains in the roadbed.
- Potential hydrocarbon contamination of local water bodies, particularily if applied excessively.

Social Considerations: Strength of odor unknown.

Reference: Saskatchewan Department of Highways n.d.

Dust Suppressant Information Sheet

Category: Petroleum Based Suppressant

Name: Asphalt Road Primer

Manufacturer/Distributor:

Application/Effectiveness:
- o Effective as a dust suppressant, however generally not recommended.
- o Surface will usually pothole eventually, deteriorating ridability.
- o Cures hard making it less desirable due to potential pothole problem.
- o Generally only one application per year.

Cost breakdowns: Not determined.

General Application Procedures: Generally applied in one pass at a rate of about 1.1-1.4 litres per square metre.

Men & Equipment (Storage) Requirements:
- o Standard Equipment.
- o Traffic control may be desired as product cures.

Preparation of Suppressant: None, applied as supplied.

Preparation of Road Bed:
- o Standard Preparation.
- o Small windrow may be left to serve as blotter during application and smoothed out after to ensure positive roadbed drainage.

Precautions/Problems:
- o Hardened crust makes road surface more difficult to rework and promotes potholing.
- o Traffic control may be desired as product cures.

Components: Asphalt and solvents.

Properties:
- o Difficult to rework.
- o Moderate fire hazard when exposed to heat or flame.

Toxicity: Contains hydrocarbons that may be potentially toxic.

Environmental Considerations:
- o Product generally remains in the roadbed.
- o Potential hydrocarbon contamination of local water bodies, particularily if applied excessively.

Social Considerations: Strength of odor unknown.

Reference: Mason et al. 1982

Dust Suppressant Information Sheet

Category: Petroleum Based Suppressant

Name: Decant Oil

Manufacturer/Distributor:

Application/Effectiveness:
- o Quite effective as a dust suppressant - may be more effective than calcium chloride or lignosulfonate and longer lasting.
- o May be costlier than other alternatives such as calcium chloride or lignosulfonates.
- o Commonly develops potholing problems.
- o May cure hard making road surface difficult to rework.

Cost breakdowns:
- o Considerably more expensive than used oil.
- o May be more expensive than other dust suppression alternatives such as calcium chloride or lignosulfonates.

General Application Procedures: Generally applied at 1.1 to 1.65 litres per square metre.

Men & Equipment (Storage) Requirements:
- o Standard Equipment.
- o No specialized storage requirements.

Preparation of Suppressant: Usually applied as supplied.

Preparation of Road Bed: Standard Preparation.

Precautions/Problems:
- o Use of petroleum products for dust suppression is generally discouraged at the provincial level in western Canada in favor of energy conservation.
- o Roads with high clay content need greater applications.
- o May be prone to potholing in very wet weather.

Components:
- o A fluxed oil which is the heaviest oil from the cracking process.
- o Equivalent to a furnace fuel or stove oil.

Properties:
- o Lighter than Bunker oil.
- o Moderate fire hazard when exposed to heat or flame.

Toxicity: Contains hydrocarbons that may be potentially carcinogenic.

Environmental Considerations:
- o Potential hydrocarbon contamination of nearby water courses, bodies, or ground water.
- o Full environmental implications of use not well researched.

Social Considerations:
- o Use of petroleum products for dust suppression is generally discouraged at the provincial level in western Canada in favor of energy conservation.
- o Smell or appearance may be less desirable than other dust suppression alternatives such as calcium chloride or lignosulfonates.

Reference: Mason et al. 1982

Dust Suppressant Information Sheet

Category: Petroleum Based Suppressant

Name: Re-refined Oil

Manufacturer/Distributor:

Application/Effectiveness:
- Quite effective as a dust suppressant - may be more effective than calcium chloride or lignosulfonate and longer lasting.
- May be costlier than other alternatives such as calcium chloride or lignosulfonates.
- Commonly develops potholing problems.
- May cure hard making road surface difficult to rework.

Cost breakdowns:
- Considerably more expensive than used oil.
- May be more expensive than other dust suppression alternatives such as calcium chloride or lignosulfonates.

General Application Procedures: Generally applied at 1.1 to 1.65 litres per square metre.

Men & Equipment (Storage) Requirements:
- Standard Equipment.
- No specialized storage requirements.

Preparation of Suppressant: Usually applied as supplied.

Preparation of Road Bed: Standard Preparation.

Precautions/Problems:
- Use of petroleum products for dust suppression is generally discouraged at the provincial level in western Canada in favor of energy conservation.
- Roads with high clay content need greater applications.
- May be prone to potholing in very wet weather.

Components: An oil that has been previously used but cleaned and refined to a level indistinguishable from virgin oil.

Properties:
- Moderate fire hazard when exposed to heat or flame.

Toxicity: Contains hydrocarbons that may be potentially carcinogenic.

Environmental Considerations:
- Potential hydrocarbon contamination of nearby water courses, bodies, or ground water.
- Full environmental implications of use not well researched.

Social Considerations:
- Use of petroleum products for dust suppression is generally discouraged at the provincial level in western Canada in favor of energy conservation.
- Smell or appearance may be less desirable than other dust suppression alternatives such as calcium chloride or lignosulfonates.

Reference: Mason et al. 1982

Dust Suppressant Information Sheet

Category: Petroleum Based Suppressant

Name: Heavy Crude Oil

Manufacturer/Distributor:

Application/Effectiveness:
- Quite effective as a dust suppressant - may be more effective than calcium chloride or lignosulfonate and longer lasting.
- May be costlier than other alternatives such as calcium chloride or lignosulfonates.
- Commonly develops potholing problems.
- May cure hard making road surface difficult to rework.

Cost breakdowns:
- Considerably more expensive than used oil.
- May be more expensive than other dust suppression alternatives such as calcium chloride or lignosulfonates.

General Application Procedures: Generally applied at 1.1 to 1.65 litres per square metre.

Men & Equipment (Storage) Requirements:
- Standard Equipment.
- No specialized storage requirements.

Preparation of Suppressant: Usually applied as supplied.

Preparation of Road Bed: Standard Preparation.

Precautions/Problems:
- Use of petroleum products for dust suppression is generally discouraged at the provincial level in western Canada in favor of energy conservation.
- Roads with high clay content need greater applications.
- May be prone to potholing in very wet weather.

Components: Heavy crude oil

Properties: Flash pt. -5 to 33°C

Toxicity:
- A recognized carcinogen.

Environmental Considerations:
- Potential hydrocarbon contamination of nearby water courses, bodies, or ground water.
- Full environmental implications of use not well researched.

Social Considerations:
- Use of petroleum products for dust suppression is generally discouraged at the provincial level in western Canada in favor of energy conservation.
- Smell or appearance may be less desirable than other dust suppression alternatives such as calcium chloride or lignosulfonates.

Reference: Mason et al. 1982

APPENDIX 2

TEST SECTION METHODS

APPENDIX 2

TEST SECTION METHODS

APPENDIX 2

A2.1 INTRODUCTION

Test sites, as referred to in this manual, are portions of roadway used for testing dust suppressants. These sites are often a continuous portion of roadway 3 to 6 kilometres in length. Test sections represent individual sections of the test site receiving individual suppressant treatments.

Test sections are often constructed by agencies responsible for dust suppression in a given area. Dust suppression performance tests are carried out on these test sections. Performance tests may be undertaken to:

- o compare suppressants available for application;
- o compare a new suppressant with one already in use; and
- o evaluate the suitability of a waste as a dust suppressant

The purpose of this Appendix is to discuss how to pick a test site and how to record the performance test results. Much of this information is based on studies undertaken by the highway ministries of British Columbia, Saskatchewan, and Manitoba (Sontowski and Vliet 1977; Mulholland 1972; Boyd and Van Cauwenberghe 1980). Some methods and insight have been taken from other studies done in the United States (Hoover 1981; Roberts 1974; Sultan 1976).

A2.2 TEST SITE SELECTION AND PREPARATION

It is important that test sites be as representative of normal dusting conditions as possible. Traffic densities, bed materials (soil testing may be desirable), climate, alignment, grade and maintenance are key criteria. The use of two or more test sites is often desirable in jurisdictions where more than one significant road condition is encountered.

Individual test sections should all:

- o be roughly of equal length
- o have similar subgrade and surface course material
- o have similar traffic density and type
- o be adjacent to each other whenever feasible
- o have a similar level of maintenance prior to selection

If quantitative dustfall measurements are to be made, the test site should preferably run perpendicular to the dominant wind direction.

At least one (preferably two) control sections receiving no dust suppressant should be planned. It is desirable to locate control sections towards each end of the test site to provide an unbiased check of uniformity across the site. Repetition of suppressant sections also adds more credibility to results.

Suppressant manufacturers and distributors usually recommend optimum application procedures for a particular area. However, test sections of various concentrations of suppressant, or various maintenance procedures, are often desirable for determining optimum performance and economy for each suppressant tested. This is particularly true when a waste product is being tested as a possible suppressant.

Areas selected as test sections should have received normal maintenance prior to suppressant application and should have had no gravel added prior to or after application. As described earlier, previous maintenance, including gravel additions, should have been consistent across all the test sections and be representative of the jurisdiction area. During preparatory blading, windrow sizes throughout the test site should be equal, indicating that similar amounts of float gravel are distributed throughout the test sections.

Any inherently weak areas in the surface course or subgrade should be noted beforehand. Test sections should be clearly marked along the road. Signs for the general public are suggested, particularly if the chosen dust measurement techniques, described in Section A2.3, will disrupt traffic.

Surface course preparation and suppressant application for all test sections should occur under the same climatic conditions. Similar treatment of all sections within the shortest time frame is desirable. Key factors to consider are summarized in Table 1.

Application of suppressants should be timed to take advantage of desirable conditions, such as naturally dampened roadbed, and to avoid undesirable conditions such as storms. Of course, only a limited degree of flexibility in timing is possible. Application generally follows the manufacturer's or distributer's recommendations unless an experimental variation in application rate or surface course preparation is desired. Preparation and application variables affecting suppressant performance are listed in Table 2.

A hypothetical evaluation of suppressant alternatives for an experimental test site is illustrated in Figure 1 and evaluated in Table 3. Note that prior dust conditions are recorded and that results are more credible when equal length test sections are used on a test site having fairly uniform bed materials. Photographs of suppressants after application are often useful.

A2.3 TEST OBSERVATIONS AND RECORDS

Observations of climatic conditions, roadbed performance characteristics and dust laying performance are required. Environmental concerns, such as dust suppressant runoff, potentially causing water pollution, also warrants discussion. Parameters most commonly assessed are listed in Table 4. A possible test section report form is presented in Figure 2.

Table 1

Key Factors in Test Section Preparation

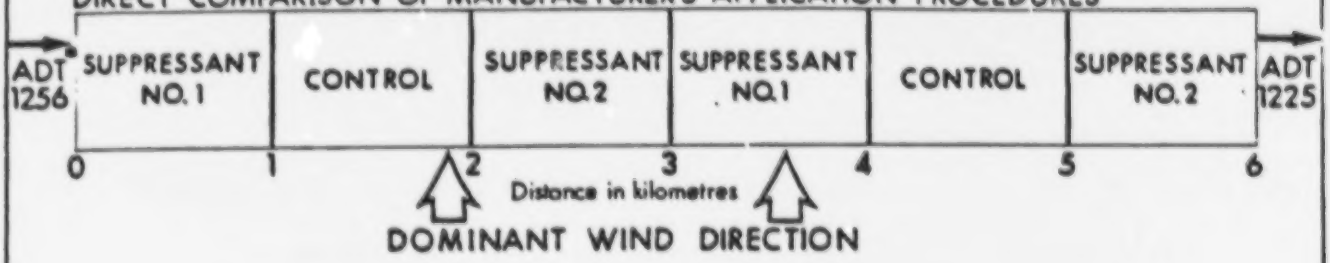
- normal maintenance of all sections prior to preparation (no gravel additions)
- similar float gravel on all test sections as indicated by windrow
- inherently weak areas noted
- test section boundaries clearly marked
- public signs if necessary
- preparation and application under same climatic conditions
- treatment of all sections within the shortest possible time

Table 2

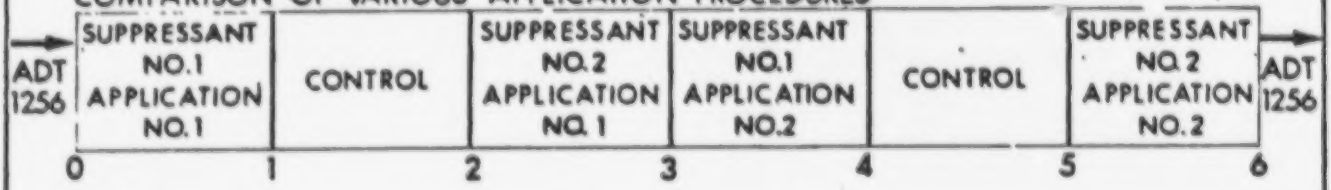
Preparation and Application Variables Affecting Suppressant Performance

Variable	Most Desirable Condition
- preblading tightness	tight bladed
- fines content of surface grade	10-25% fines (<200 sieve)
- moisture condition during blading	optimum dampness
- moisture condition during application	optimum dampness
- application rate	minimize runoff, pooling
- number of passes	minimize over-penetration
- drying/penetration time of suppressant	prevent rapid drying or penetration
- weather before, during, after application	not too hot or dry, no rain
- compaction after application	rolled afterwards
- float gravel before and after application	minimal
- traffic density and type	observed-representative of area
- maintenance after application	minimize deterioration

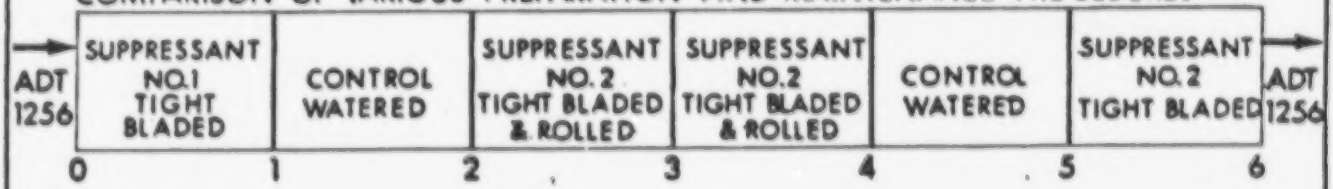
DIRECT COMPARISON OF MANUFACTURER'S APPLICATION PROCEDURES



COMPARISON OF VARIOUS APPLICATION PROCEDURES



COMPARISON OF VARIOUS PREPARATION AND MAINTENANCE PROCEDURES



*ADT – Average Daily Traffic (Number of Vehicles)

FIGURE 1

SAMPLE TEST SECTION DESIGNS

PREPARED BY

Tachman Engineering Ltd.

Table [illegible]

Hypothetical Test Site Evaluation of Suppressant Alternatives

Section - Treatment	I - Suppressant 1	II - Control	III - Suppressant 2	IV - Suppressant 1	V - Control	VI - Suppressant 2
Kilometre	0	1	2	3	4	5 6
Subgrade						
0 - 4 cm Plasticity Index -200 5 - 15 cm Plasticity Index -200	8% 13% 6% 39%	0 15 4 45	0 17 2 35	3 14 5 38	0 8 3 33	5 12 7 43
Date of treatment Weather conditions	Treatment A - June 30/81; Treatment B - Aug. 17/81 Warm, dry, slightly overcast; cool, humid, overcast					
Pretreatment dust rating (see Fig. A2-2)	A - 2 B - 3	A - 2 B - 2	A - 3 B - 3	A - 3 B - 3	A - 2 B - ?	A - 2 B - 3
Roadbed preparation/man-hours, equipment	A - Watered, light bladed, 6 manhours, water truck, grader B - Light bladed, 4 manhours, grader					
Suppressant preparation/ manhours, equipment	Both A & B prepared and applied by distributors using their equipment Suppressant 1 20% solution, Suppressant 2 1:2 with water - if truck was full, would have needed water truck (about 3 manhours per truck-load)					
Application, passes/ manhours, equipment	A - Suppressant 1 3 l/m^2 in 2 passes, 3 manhours/km, self propelled packer; Suppressant 2 2 l/m^2 in 2 passes, 4 manhours/km, self propelled packer. B - Suppressant 1 1.5 l/m^2 in 2 passes, 2 manhours/km, self propelled packer; Suppressant 2 1.5 l/m^2 in 2 passes, 3 manhours/km, self propelled packer.					
Suppressant cost	A - Suppressant 1 $1300/km; Suppressant 2 $1366/km B - Suppressant 1 $875/km; Suppressant 2 $1025/km					
Suppressant observations	A -Some pooling and runoff, penetration to about 5 cm B -More pooling, less penetration		A/B -Some pooling, set in 8 hours -Penetration to 3 cm -Formed light-brown crust about 1 cm, flexible	A -No pooling, penetration to about 8 cm B -Some pooling and runoff -4 cm penetration		A -Same as Section III B -No pooling, set in 6 hours -Penetration to 1 cm
Traffic	Total axles, June 30 - September 15, 1981 = 20,550; adjusted average daily traffic = 211; commercial vehicles = 25%					
Average temperature	July 16.7°C		August 13.3°C		September 10°C	
Average relative humidity	July 73%		August 77%		September 90%	
Total precipitation	July 14.94 cm		August 3.73 cm		September 0.76 cm	
Average dust rating (see Fig. A2-2)	A - 4.6 B - 4.2	A - 1.5 B - 1.1	A - 4.0 B - 4.4	A - 3.8 B - 4.0	A - 1.8 B - 1.2	A - 4.3 B - 4.5
Performance observations	A -Some washboarding, some ravelling B -Some potholes	A -Severe washboarding B -Some potholes	A -A few potholes, a little ravelling B -A few potholes	A -A little washboarding, some ravelling B -Some potholes	A -Severe washboarding B -Some potholes	A -No potholes, a little ravelling B -Some potholes
Maintenance/manhours, equipment. (g=grader, w=watertruck)	A -30 hrs, g + w B -30 hrs, g + w	A -60 hrs, g + w B -65 hrs, g + w	A -20 hrs, g B -20 hrs, g + w	A -35 hrs, g + w B -30 hrs, g + w	A -55 hrs, g + w B -60 hrs, g + w	A -20 hrs, g B -20 hrs, g
Average cost/kilometre	$4133 Suppressant 1	$3750 Control	$3801 Suppressant 2	$4283 Suppressant 1	$3450 Control	$3801 Suppressant 2
Conclusion	In this hypothetical example, Suppressant 2 proved marginally superior in performance, at the least cost, and would be recommended for dust suppression in the area under current pricing.					

Table 4

Basic Observations of Roadbed and Climatic Conditions

Roadbed Performance	- surface condition - suppressant condition - riding quality - performance characteristics - maintenance since last inspection (include date) - problem characteristics - density (relative) - float gravel - ravelling - potholing/washboarding - wheel-well noise - apparent run-off of suppressant
Climatic Conditions	- preceding weather conditions - time - temperature - relative humidity - precipitation - total - duration - cloudiness - wind-speed and direction

A2.3.1 Dust Observations and the Observation Sheet

Estimations of dust emissions can be made by visual observation or through an air sampling program.

A2.3.1.1 Visual Estimation of Road Dust Emissions

A visual (subjective) approach appears to be a successful means of estimating dust generation. A scale is used to evaluate the dustiness of a road. Two scales have been used in northern and western Canada - one from 0 to 5 (Figure 2) and the other from 0 to 10 (Table 5). Both scales are based on a minimum visibility (maximum dustiness) of zero. The scale of dustiness from 0 to 5 appears more suitable since it is very difficult to distinguish between the 11 degrees of dustiness as defined in the 0 to 10 scale.

Road dust generation levels, on both scales, is not considered unsatisfactory until visibility is restricted so as to impair safety. This may not satisfy all the public but provides an economical balance by allowing longer dust suppressant life without endangering driver safety.

Photographs of the dust generated by a passing test vehicle are useful. These photographs provide a permanent record for the visual estimation evaluation process. To obtain evaluation photographs the following procedure should be followed:

1. Mark off a distance (30 - 50 metres) between the camera and a fixed point along the test section of road (Figure 3).

2. Drive a test vehicle at a predetermined constant speed past the camera towards the fixed point.

3. Take a picture when the test vehicle has pass the fixed point.

Figure 2.

Test Section Report Form

Test Section _____
Test Site _____
Inspection # _____
Inspector _____

Date _____ Time _____

Photos: Roll#___ Picture #___

I WEATHER

Preceding Conditions _____

Temperature _____ Cloudiness _____

Rel. Humidity_____ Wind- Speed _____
- Direction_____

Precipitation - total _____
- duration _____
- disturbance type _____

II ROAD SURFACE CONDITION

Maintenance since last inspection: procedures/dates/reasons _____

Surface Condition _____ Float Gravel _____

Roadbed Density _____

Palliative Condition _____

Performance Characteristics: Wheelwell noise_____ Potholes _____
Ravelling _____ Washboarding_____

Problem Characteristics _____

III DUST RATING (Circle the rating(s) that most closely describes the condition existing on the roadway. If condition is between two ratings circle both ratings).

Rating	Condition
5	- Dust free, no dust rises from passing vehicles.
4	- Thin dust, rises a few feet high when vehicle passes.
3*	- Thin dust cloud, rises well above passing vehicles, vision not restricted.
2	- Thin-thick dust cloud, visibility fair to poor, dust drifting from roadway.
1	- Thick dust cloud, causes driver uncertainty when following, heavy dust drifting.
0	- Extreme dust conditions, takes 1-5 seconds for visibility to improve, visibility greatly restricted.

* Minimum acceptable dust rating.

IV COMMENTS (i.e. Inherent problem areas, palliative runoff, environmental observations, etc.)

Table 5

Rating Scale of Dust Conditions (0-10)

RATING	CONDITION
10	- Dust-free
9	- Very little dust, rising one to two feet
8	- Small amount of dust, rising to fender level
7	- Thin cloud, easily seen through, no impaired vision
6*	- Cloud thickens and thins, visibility restricted in flashes, normal driving speeds maintained at all times, no uncertainties in manoeuvres
	LEVEL OF SAFETY IMPAIRMENT
5	- Dust causes driver to be uncertain momentarily because of poor visibility in meeting or passing
4	- A blast of dirt taking one to five seconds to clear, visibility restricted during this time if meeting. Forced to drop back a short distance if following or take a risk if passing
(3,2,1)	- Concentration of dust and time between 0 & 4
0	- Dust is suspended and concentrated. Next-to-zero visibility for 1/2-mile.

* Minimum acceptable level of dust abatement.

Source: Mulholland 1972

FIGURE 3

USE OF PHOTOGRAPHS TO RECORD DUST CONDITIONS

PREPARED BY

A2.3.1.2 Air sampling of Road Dust Emissions

Air sampling (dustfall measurement) is essential for evaluating suppressant effectiveness from an aesthetic or environmental point of view. The data collected enables field personnel to determine the amount of dust which is suppressed by a suppressant. This information would be useful in:

- o evaluating the cost of suppressing a kilogram of dust; and
- o responding to citizen complaints by providing backup data.

In the United States, elaborate field and laboratory testing of suppressants has included the use of:

- o fans and blowers to direct dust towards a high-volume sampler.
- o abrasion apparatus; and
- o wind tunnels.

However, quantitative dust measurement in the field is generally done with dust emission samplers or dustfall collectors.

Dust Emission Samplers

A dust emission sampler basically consits of a high-volume vacuum that can be calibrated, together with a filtering device for collecting the sample. Trade names include Hi-Vol samplers (some of which can divide the sample according to particle size), impacters and membrane air samplers.

The dust emission sampler may be positioned in two ways to measure the amount of dust generated by a test vehicle. The first method is by towing the sampler behind the test vehicle. The distance between the vehicle wheels and the sampler is recommended to be two metres with the inlet at 30 centimeters above the surface. The second method of measurement is to position the dust emission sampler on the shoulder of the road, with the inlet at a constant height.

Dustfall Collection

Dustfall collection involves the use of open-topped containers which generally contain water as a dust-collecting medium. When exposed for a known period of time, the rate of dustfall deposition can be established.

Dustfall Station Construction and Operation

Dustfall stations can be easily constructed in the shop from readily-available materials. A dustfall station consists of a suitable container to collect dust, a device to hold the dust collector and a support stand.

Alberta Environment (1976) employs open-top polyethylene juice dispensers (1.4 L) as dust collectors. These containers are fitted with sealing lids when collected for transport to the laboratory. Juice tins (1.4 L) are suggested as holding devices, although concrete cylinders or other suitable plastic containers have been successfully used.

The holding container (tin cylinder) is fastened to a piece of steel pipe (2.5 cm diameter, 1 metre long), which in turn is fastened to a support stand by means of steel wire strapping. Stand materials have included angle iron, tree stumps or fence posts.

For operation of a dustfall station, distilled water (500 ml) is added to the dust collector as a means of suspending dust. A 1% solution of Dowicide 'B' or quatenary ammonia should be added to the collector if necessary, to inhibit algae growth. During cold weather the collector is filled with ethylene glycol to prevent freezing or may be exposed if non-freezing solutions interfere with lab analysis. If a commercial laboratory is used for the dust analysis, the laboratory will often provide the dustfall collectors with collection media.

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Dustfall collectors are retrieved after a designated exposure (sampling) period and replaced with new collectors if continued monitoring is desired. A sampling period is generally 30 days with an allowance of plus or minus two days. For detailed studies, a sampling period of one week is common. During the exposure period, periodic field inspections should be made, particularly during periods of heavy rainfall. If dustfall collectors are apt to overflow, they should be replaced. The laboratory will generally recommend if dustfall stations should be altered or protected to discourage contact by birds or wildlife.

It is crucial that collectors be properly covered during transit.

A typical dustfall station is illustrated in Figure 4.

Site Selection and Dustfall Stations

Selecting a proper site for a dustfall station is important. An improper site may result in foreign matter falling into the dustfall canister, contaminating the sample. In general, an ideal dust monitoring station should be at least 0.5 metres above the ground. In addition, the elevation angle to the top of any obstruction should be less than 30 degrees (Figure 5). If these precautions are taken, the potential for sample contamination should be severely reduced.

In establishing a dustfall monitoring system along a test section of road at least two monitoring sites per test section are recommended. A monitoring site consists of two dustfall collectors, one on each side of the road equal distances from the centreline.

Figure 6 illustrates a sample test section with dustfall stations. Dustfall collector heights relative to the road crown should be similar for all stations. In sloping terrain, where collectors cannot be at the same height, the data from each collector should be analyzed separately.

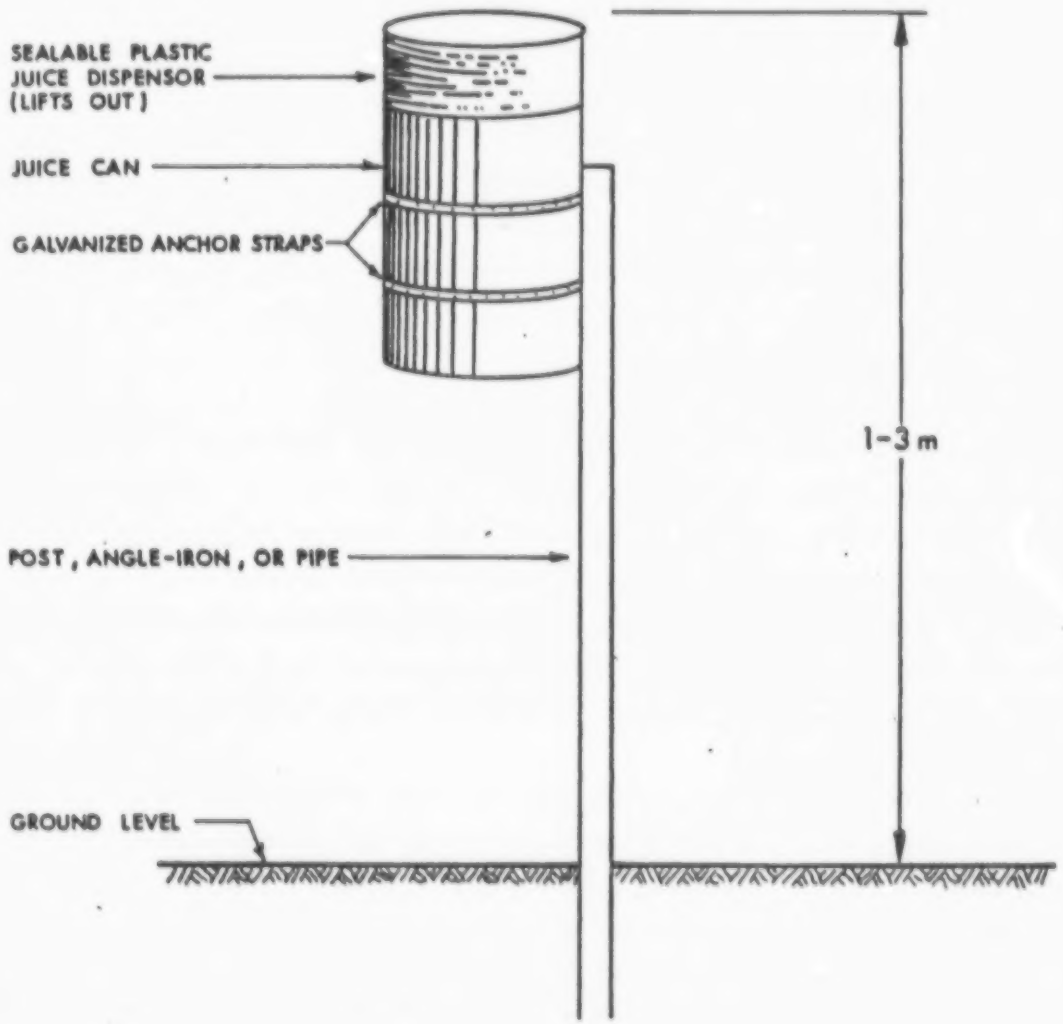

FIGURE 4

DUSTFALL STATION

PREPARED BY

Techmm Engineering Ltd.

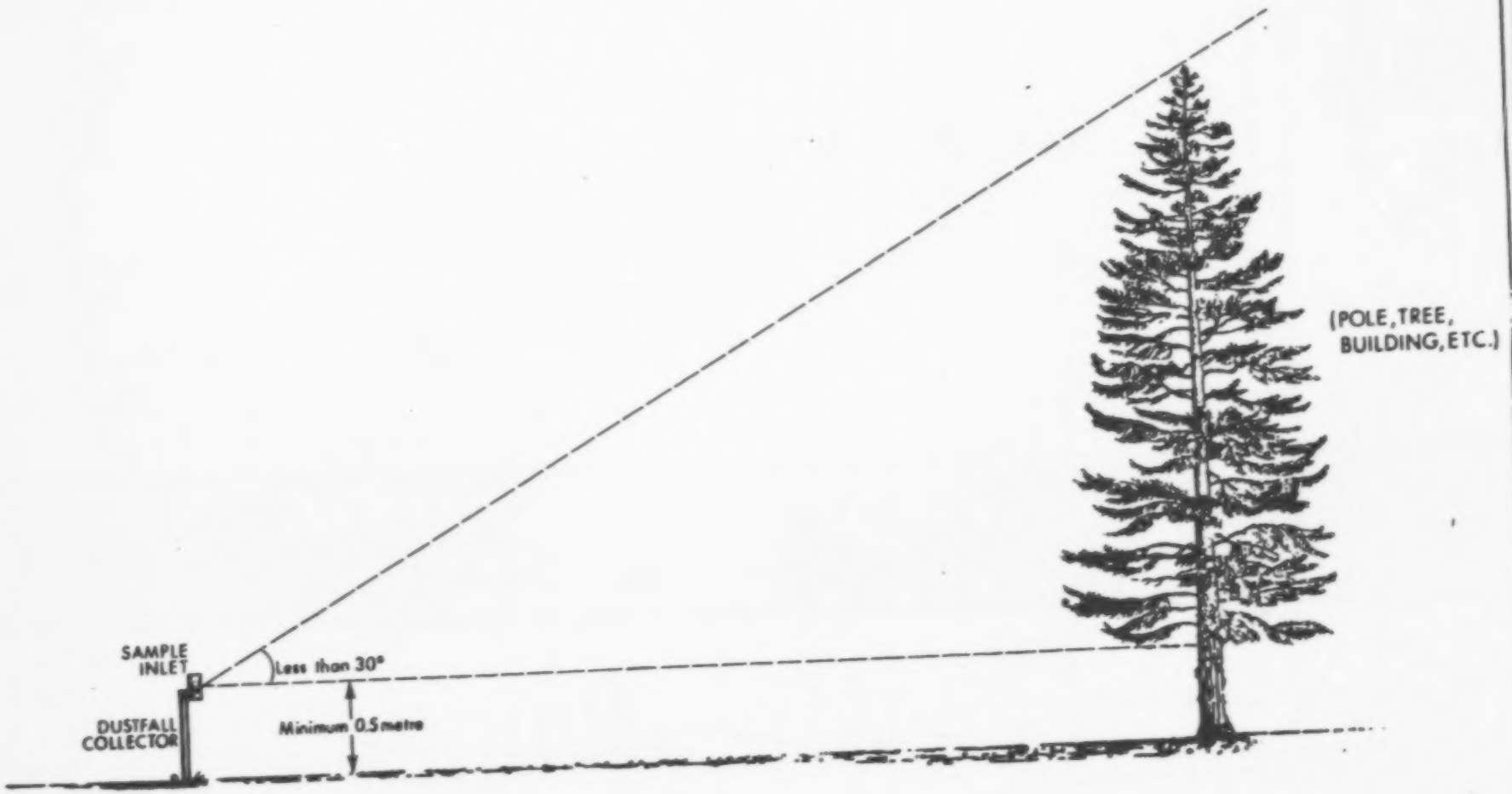

FIGURE 5

SITE SELECTION CRITERIA FOR DUSTFALL STATION

Adapted from ALBERTA ENVIRONMENT 1976

PREPARED BY
Techman
Engineering
Ltd.

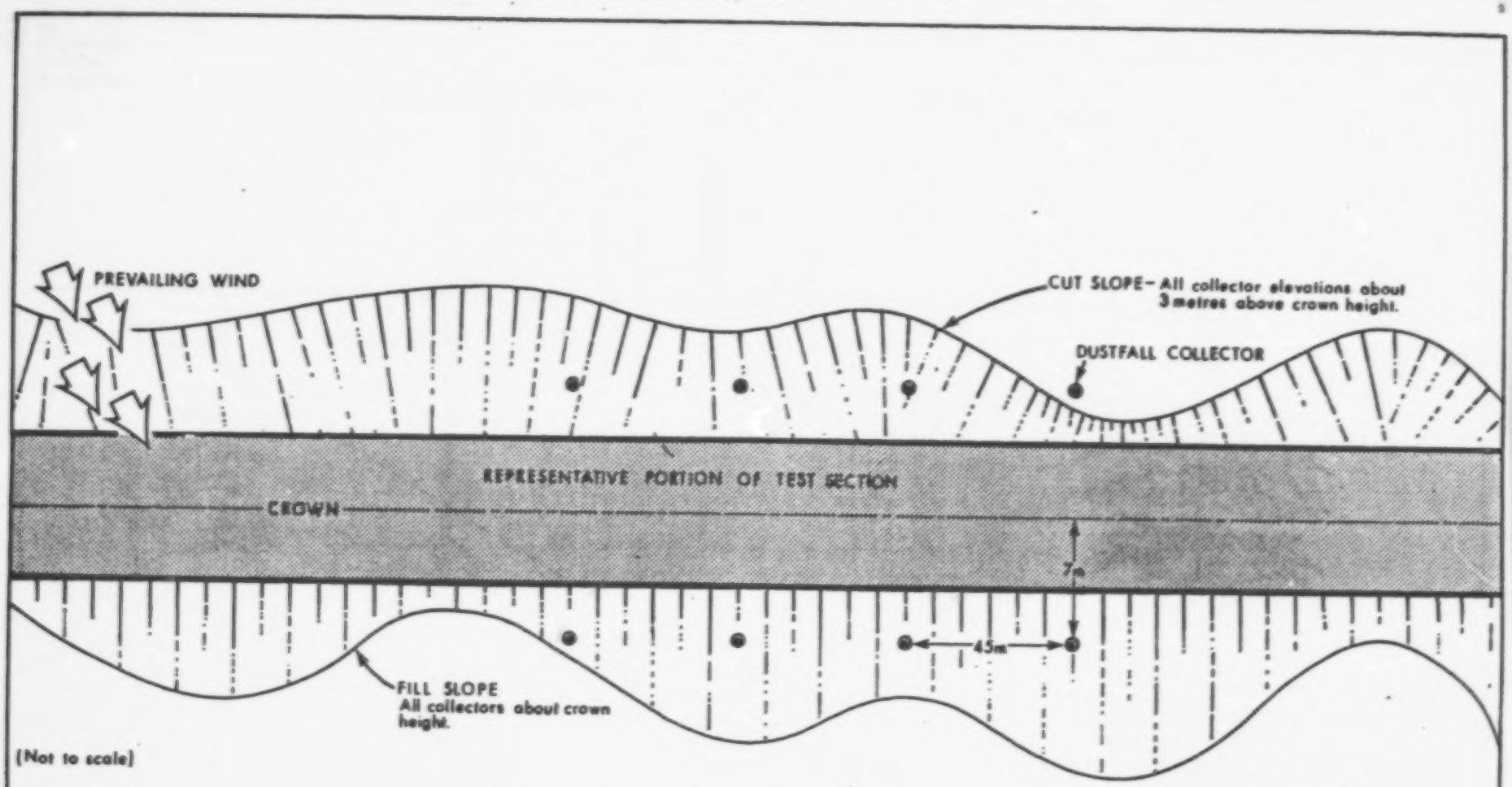

FIGURE 6

SAMPLE TEST SECTION WITH DUSTFALL STATIONS

(After Senzowski and Vilet 1977)

PREPARED BY
Techmon Engineering Ltd.

Dust Analysis

Dust quantity analysis is usually done by commercial laboratories and includes the removal of organic matter and subsequent measurement of dust collected. Special analyses, such as particle size analysis or geological origin, are generally available. Results are normally expressed in dust weight per area per number of vehicles or days.

A2.3.2 Environmental Monitoring

All dust suppressant evaluation programs should have an environmental and social impact component.

Monitoring programs should address the effect of the suppressant on water quality, vegetation, soils and roadside development. These monitoring programs should be developed in consultation with provincial environment authorities.

APPENDIX 3

SELECTED METRIC CONVERSION FACTORS

APPENDIX 3

Selected Metric Conversion Factors

	Multiply	By This	To Obtain
Length	in.	25.4	mm
	ft.	0.30	m
	yd.	0.91	m
	mi.	1.61	km
Area	sq. yd.	0.84	m^2
Volume	cu. ft.	0.03	m^3
	cu. yd.	0.76	m^3
	fl. oz.	28.41	mL
	gal. UK	4.55	L
	gal. US	3.79	L
Mass	lb.	0.45	kg
	short ton	0.91	t
Density (linear)	lb./ft.	1.49	kg/m
	lb./mi.	0.28	kg/m
Density (area)	lb./sq. ft.	4.88	kg/m^2
Concentration or Density (mass)	lb./cu. yd.	0.59	kg/m^3
	lb./gal.	99.7	kg/m^3
Flow Rate (Volume)	gpm.	0.08	L/s

Source: Canadian Mining and Metallurgical Industries' Handbook of Metric Information

POOR

QUALITY

ORIGINAL